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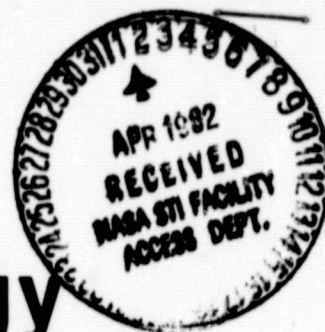
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National Aeronautics and
Space Administration

Lyndon B. Johnson
Space Center
Houston, Texas

Research and Technology Annual Report



FY-1981

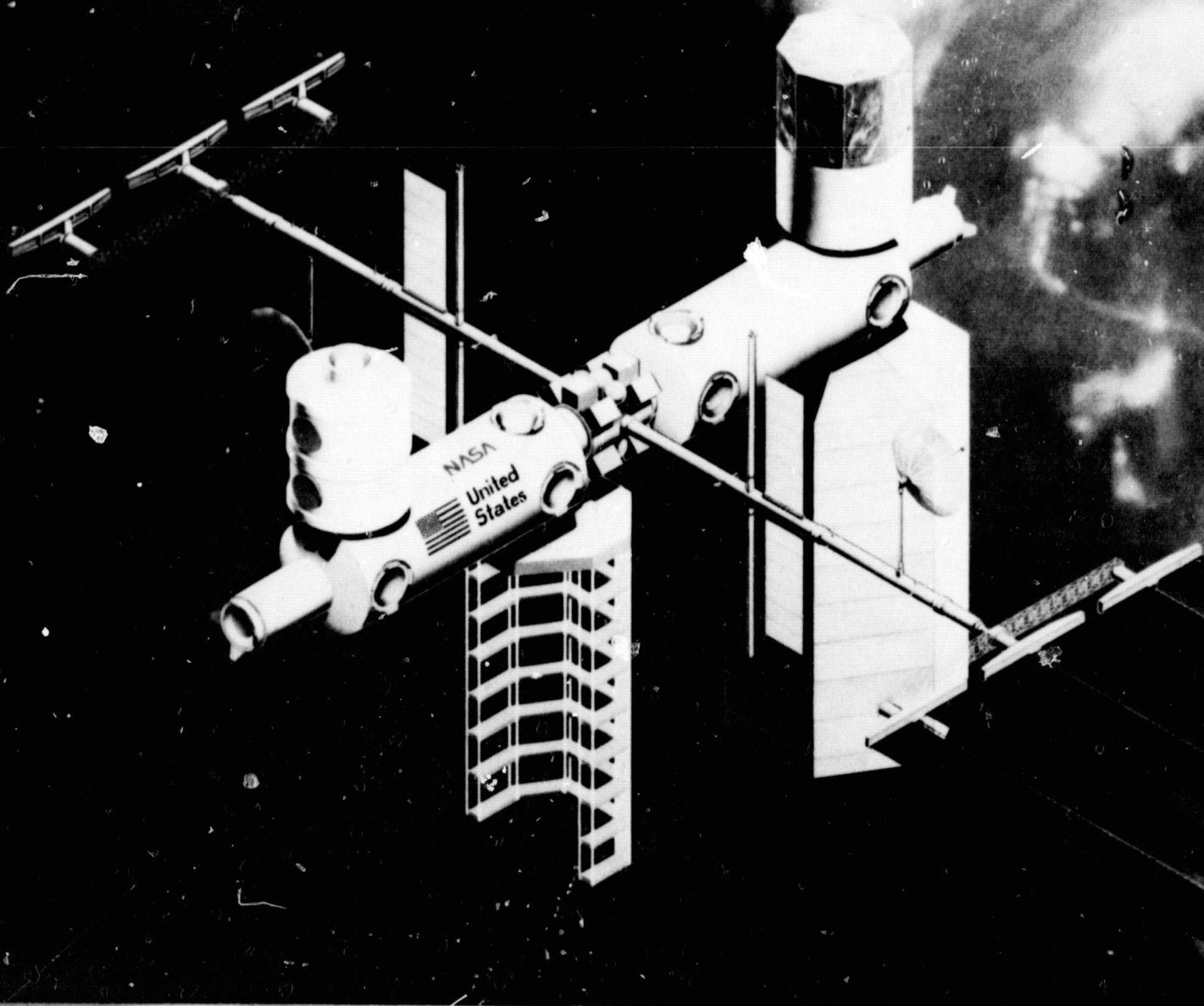
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National Aeronautics and
Space Administration

NASA

Lyndon B. Johnson Space Center
Houston, Texas
77058

Re: AT2

DEC 10 1981

Dr. Hans M. Mark
Deputy Administrator
National Aeronautics
and Space Administration
Washington, DC 20546

Dear Hans:

Enclosed are two copies of the 1981 Johnson Space Center R&T Report prepared in accordance with your instructions. The report covers significant RTOP activity sponsored by the Office of Space Transportation Systems, the Office of Aeronautics and Space Technology, the Office of Space Sciences and the Office of Space and Terrestrial Applications. Although the funding of these activities is small in comparison with mainline programs, I view these investigations as a key to continued future mission success. They are closely coordinated with the 5-year plan in order to provide a balanced technology base for the 1980's new initiatives.

Sincerely,



Christopher C. Kraft, Jr.
Director

Enclosures

cc:
NASA Headquarters

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ARC/Director
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MSFC/Director
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**Research
and
Technology
Annual Report
FY-1981**

Space Transportation Systems
Aeronautics and Space Technology
Space Sciences
Space and Terrestrial Applications

Prepared by
Program Planning Office
Technical Planning Office
Code: AT

November 1981

Preface

This report is prepared on an annual basis for the purposes of highlighting the fiscal year research and technology (R&T) activities. Its intent is to better inform the R&T Program Managers of significant accomplishments that promise practical and beneficial program application. The report is not inclusive of all R&T activities.

This document will be updated November 1 of each year.

The JSC Annual R&T Report is compiled by the Technical Planning Office, Office of the Center Director. The personnel listed below have coordinated the technical inputs for their respective sections of the report. Detailed questions may be directed to them or to the technical monitors listed in the Significant Task indices.

M. E. Goodhart/Code AT2 713-483-2703	Space Transportation Systems
L. C. Krchnak/Code AT2 713-483-2703	Aeronautics and Space Technology
Dr. J. L. Warner/Code SA 713-483-2781	Space Sciences
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Space Transportation Systems

Office of Space Transportation Systems

Summary

The mission of the Office of Space Transportation System encompasses the following three major long-term activities:

1. To provide easy, low cost access to, from, and in space for user-developed payloads to achieve their space objectives.

2. To develop flight systems to enhance the Space Transportation System's unique capabilities and its role in the use of space.

3. To develop more effective capabilities for man to live, work, and explore in space for extended periods.

The goals for the continuing accomplishment of the space transportation mission objectives in the 1980's

are outlined in figure 1. They are as follows:

1. To complete the *acquisition and upgrading* of the Shuttle/Spacelab fleet, inertial upper stage (IUS), spinning solid upper stage (SSUS), and all required ground facilities and to operate them on a routine basis by the mid-1980's.

2. To develop a *manned permanent facility* for operations construction and research in low-Earth-orbit and to routinely operate it by the end of the 1980's.

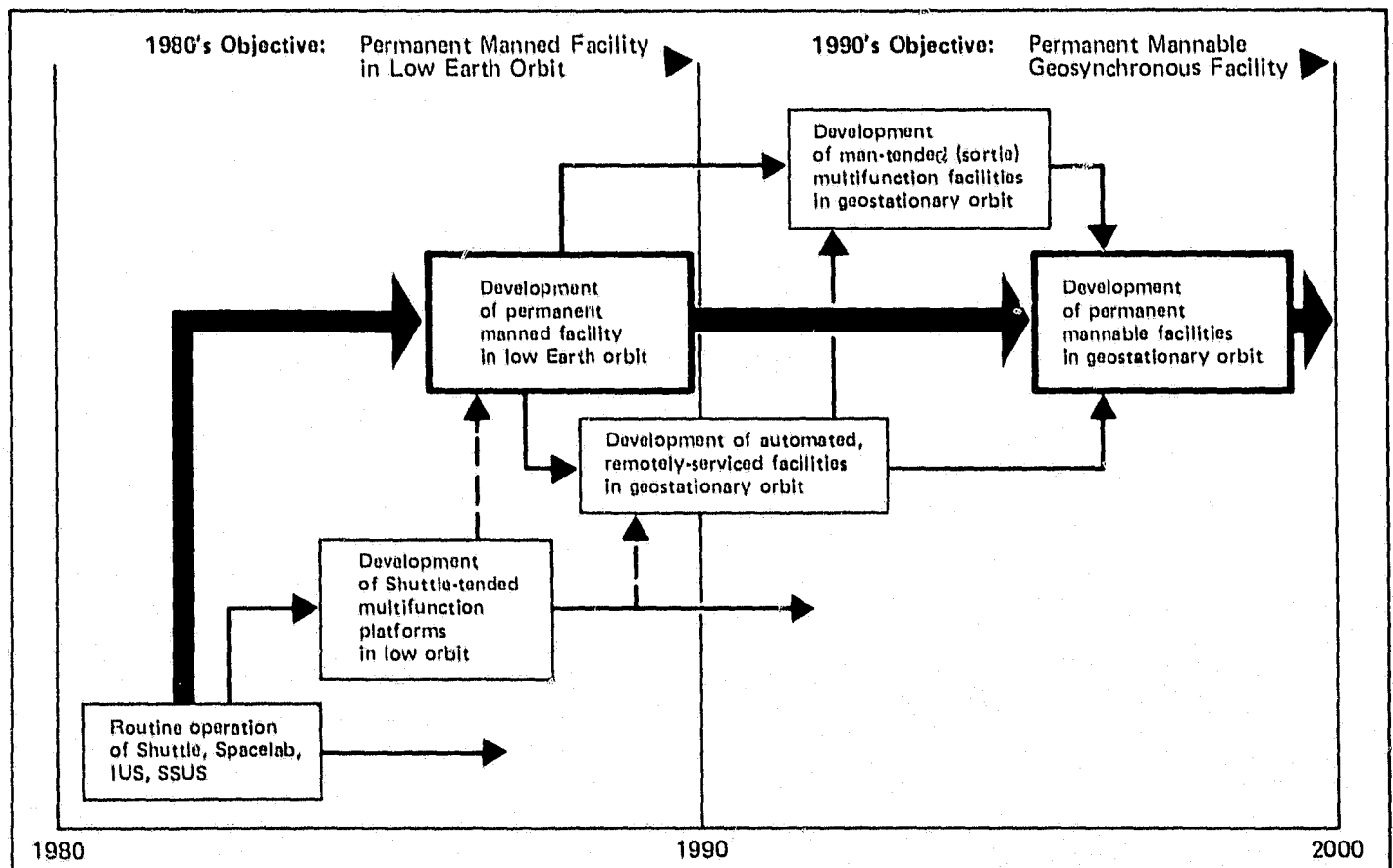
3. To develop unmanned, multi-function, low-Earth-orbit, Shuttle-tended, free-flying *Space platforms* and to operate them on a routine basis

beginning in the mid-1980's.

4. To develop permanent manna-ble multifunction facilities in *geostationary orbit* for operation by the late 1990's. This objective requires a major reduction in the cost of space transportation.

The Johnson Space Center will be a major participant in the development and operation of all of these Space Transportation System initiatives during the 1980's. The two areas of current maximum emphasis include those tasks required to bring the Space Shuttle into operational status and the pursuit toward early initiation of a permanently-occupied orbital Space Operations Center.

Figure 1.—OSTS long-range goals.



STS Upgrading Activities

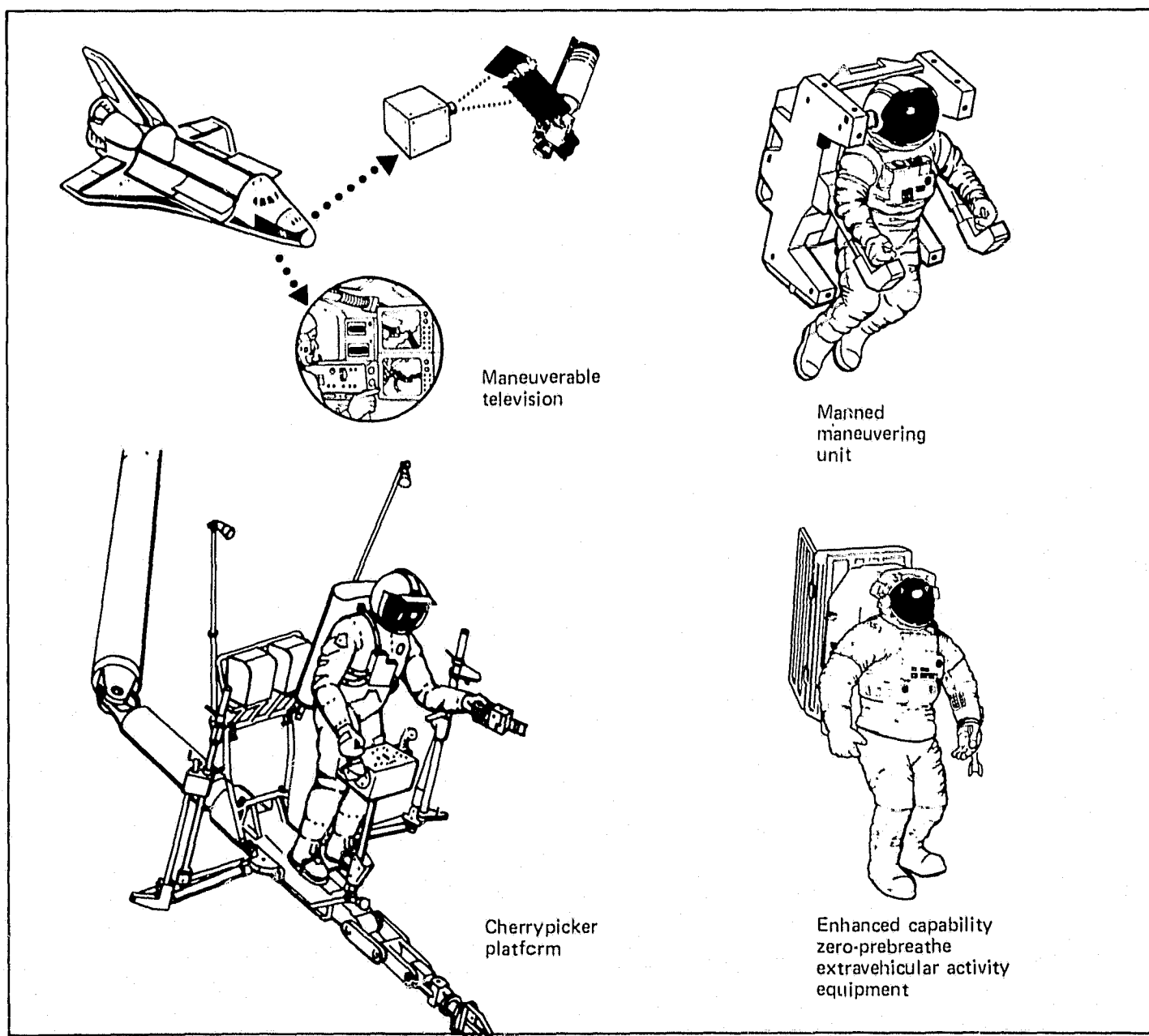
The Space Shuttle will provide for the first time a routine capability to repair, service, or return satellites as the need arises. JSC continues to investigate systems that will enhance and upgrade the STS in the performance of these tasks. The manned maneuvering unit has been reported in earlier issues of this document. Its design is completed and awaiting final mission assignment. Also awaiting project approval is the Power Extension Package (PEP). The PEP is a lightweight foldup solar array which will provide in-

creased power and/or extended shuttle mission durations of up to 20 days in orbit. The Maneuverable Television is another servicing device under in-house development at JSC. Flown remotely model-airplane style, with a range of about 3 miles, this Maneuverable Television system can provide video and telemetry data back to the Orbiter prior to satellite servicing or retrieval. Also in the development stage is the Open Cherrypicker, a movable work station controlled by an astronaut on the tip of the remote manipulator arm.

Twin studies are currently under-

way to identify other servicing requirements and the aids necessary to accomplish them. Also reported in this volume is work toward a new space suit that will greatly reduce crewman prebreathing requirements. Finally, upgrading investigations into piloting aids for proximity operations between the Orbiter and free-flying satellites are being pursued in order to minimize propellant consumption and pilot fatigue. The identification and development of these and other STS aids will be a continuing activity as orbital missions become more frequent in the early 1980's.

Figure 2.—Satellite servicing aids.



Space Operations Center

The Johnson Space Center continues to vigorously support the development of a permanently manned low-Earth-orbit facility as the agency focus for the 1980's. JSC also supports the concurrent development of a space-based orbital transfer vehicle as a necessary companion element of the Space Transportation System. The Space Operations Center (SOC) is intended to provide a permanent orbital facility for servicing of satellites, space basing of reusable upper stages, assembly of large payloads and stage, and for conducting long-duration manned science and application endeavors.

The SOC Program Office was recently formed to focus Johnson Space Center managerial, technical, and budgetary efforts related to SOC and to develop the plans and documentation necessary to support early agency initiation. Current activities are focused on incremental buildup approaches for the SOC with a goal toward early operations under a constrained budget, while preserving the capability for growth as functional needs are developed.

The current SOC-related activity at JSC involves a contingent of approximately 50 program office and directorate specialists. The SOC is currently targeted as a new initiative in 1985

with initial operational capability in 1988. Figures 3 and 4 depict the interim and growth configurations of the SOC as defined by the SOC Program Office.

Regenerable concepts that recover oxygen and water from metabolic wastes are being developed for extended duration Orbiter and Space Operations Center applications. The Advanced Life Support Laboratory has been developed at JSC for evaluation of the regenerable concepts. The test program plan includes both unmanned laboratory testing and long-duration manned chamber evaluation testing of regenerative environmental control and life support subsystems.

Testing of a process that recovers potable water from urine, using a vapor compression and distillation technique, has been completed. Electrochemical and catalytic processes that accomplish the removal of carbon dioxide and makeup of oxygen in a cabin atmosphere are now undergoing individual tests, then groupings of processes will be evaluated for system-level effects.

A 20-foot diameter vacuum chamber has been modified to accommodate the installation of the regenerative life support subsystems. A system configuration for air and water recovery that includes many of the processes baselined for the SOC will be built and subjected to extensive unmanned and manned testing.

Figure 3.— Space Operations Center interim configuration.

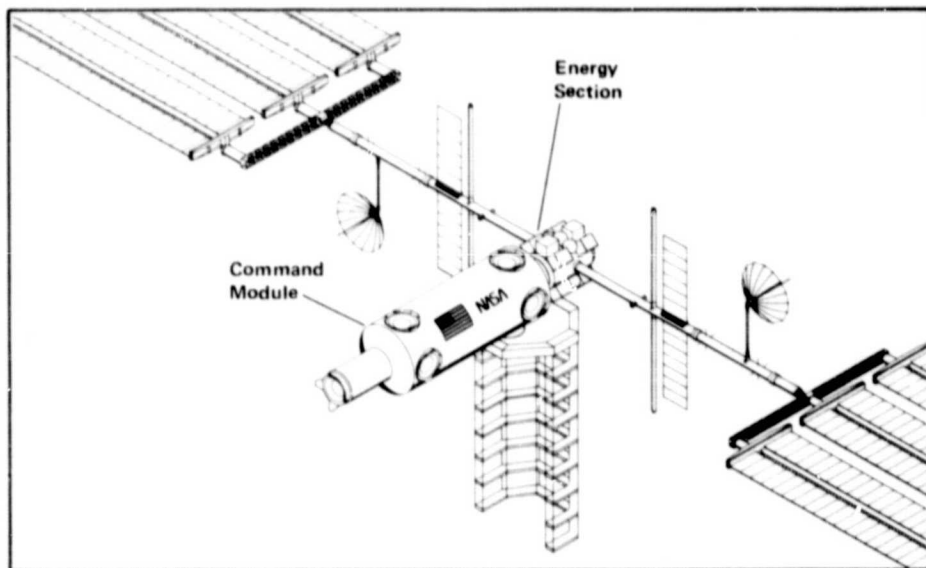


Figure 4.— Space Operations Center growth configuration.

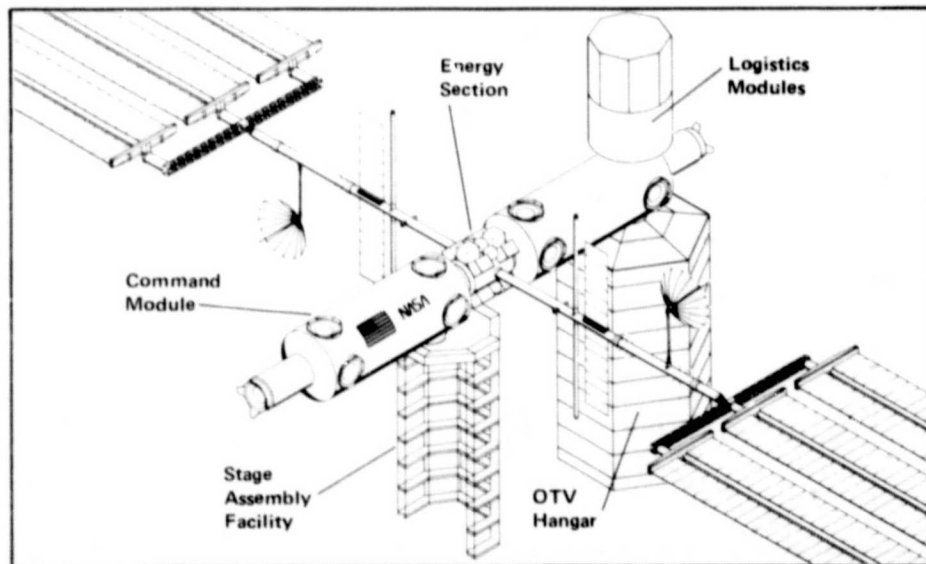


Figure 5.— Advanced Life Support Development Laboratory.



Space Platform - Space Transportation System (STS) Integration Studies

The free-flying space platform will be launched and serviced by the Shuttle. Rendezvous with and berthing to the Shuttle will also be required for payload changeout and periodic maintenance. Although the Marshall Space Flight Center (MSFC) has the responsibility for defining and developing the space platform, JSC as the Shuttle operator/integrator must conduct integration studies to insure that the safe and technically-feasible servicing operation can be performed by the STS. In order to conduct these integration studies, a baseline reference mission (BRM) was first established. The BRM described the general procedure for the initial launch and deployment mission of the space platform and payload. Spacecraft functions, crew timelines, and consumables utilization were included in the resulting BRM. This was done for all processes including space platform deployment, systems checkout, appendage operation, rendezvous, reboost, and payload checkout. The results of the BRM were then used in other subsequent integration and development studies by JSC, Rockwell, MSFC, TRW, and McDon-

nell Douglas Astronautics Company (MDAC).

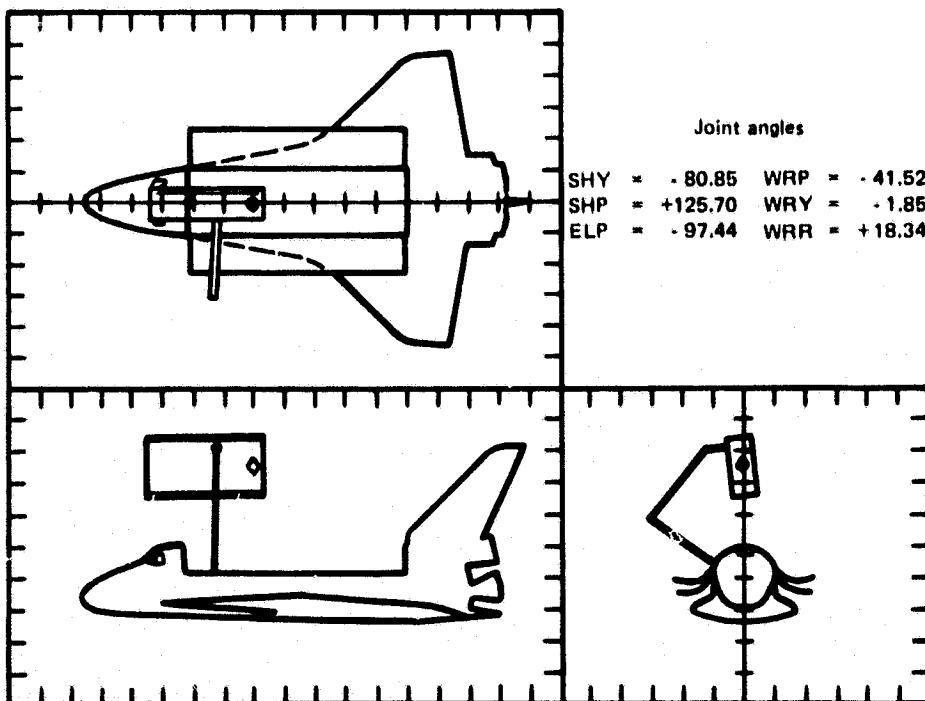
Deploying the space platform from the payload bay, berthing it to the Orbiter, and berthing payloads to the space platform will be done by using the Orbiter's Remote Manipulator System (RMS). The movement limitations of the RMS in doing these tasks were studied and defined by the use of a computerized RMS kinematic simulation system. The simulation system also was further refined through the conduct of these analyses. A sample printout of the RMS movements is shown in figure 6.

The free flying space platform will be launched by the berthed to the Shuttle during times of maintenance and payload changeout. While it is in the berthed configuration, the space platform may reflect thermal energy to the Orbiter's payload bay door thermal radiators from the Sun and also back from the radiators. Also, in the berthed position, the power system may block the Orbiter's communications antennas from transmitting to and/or receiving from the Tracking and Data Relay Satellite System. Studies were conducted to define these blockage effects at various orientations.

These are samples of the kind of space platform-STS integration

studies that will need to be done and refined for the space platform as it becomes better defined. Additional studies to be conducted in the future will include structural analysis, dynamic interaction, stabilization and control, crew interface, RMS interaction, and space platform operations analysis. JSC will provide this type of analysis for all major new initiatives as they evolve.

Figure 6.—RMS Kinematic Simulation System display.



Geostationary Orbit Activities

By the late 1990's, multifunction facilities in geosynchronous orbit will be routinely visited utilizing the Space Operations Center as a staging and logistics base. For several years, JSC has studied the systems required for manned geosynchronous mission activities. Figure 7 depicts the crew module identified for this class of activity. It is envisioned that large serviceable platforms will require on-orbit construction from raw materials carried to the site by the Space Transportation System. Construction experiments have been defined to understand the complex structure/Shuttle or structure/SOC interactions and are reported herein. Additionally, the definition of an automated-beam-fabrication machine for construction of large structures through a geodetic beam approach shows great promise in this era. Figure 8 illustrates the beam machine that would be carried into orbit in the Space Shuttle.

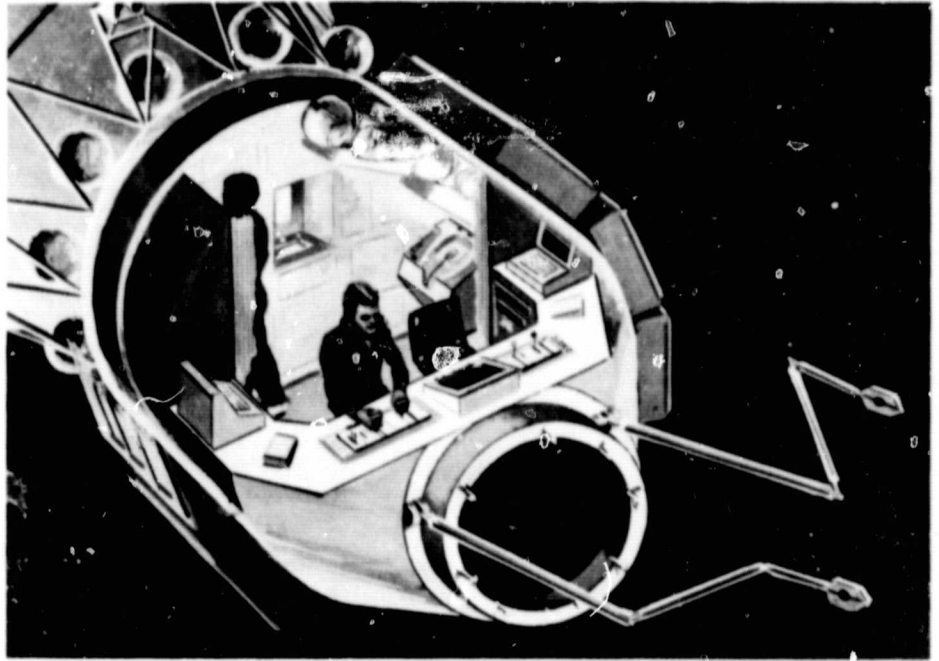
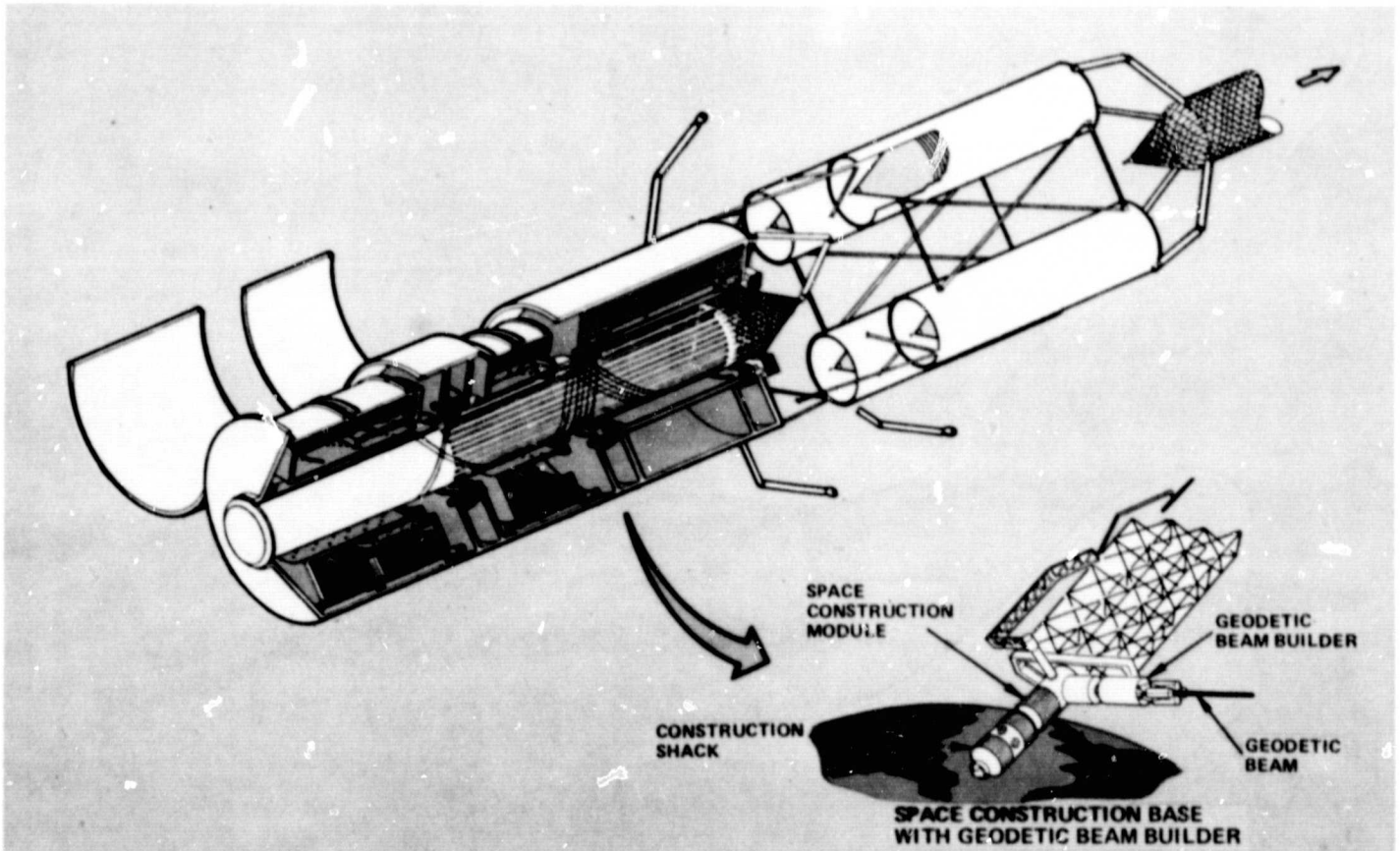


Figure 7.— Manned orbital transfer vehicle crew module.

Figure 8.— Geodetic beam fabrication machine.



Office of Space Transportation Systems

Significant Tasks

11 Satellite Services System

Funded by: Major Systems Studies (UPN-906)

Technical Monitor: G. Rysavy/EW3

Task Performed by: Grumman Aerospace Corporation

Contract NAS 9-16120

Lockheed Missiles and Space Company

Contract NAS 9-16121

12 Manned Remote Work Station Development

Funded by: Advanced Development (UPN-906)

Technical Monitor: W. W. Lofland/EW

Task Performed by: Grumman Aerospace Corporation

Contract NAS 9-15881

13 Maneuverable Television

Funded by: Advanced Development (UPN-906)

Technical Monitor: R. H. Gerlach/ED4

Task Performed by: Lockheed Engineering and Management
Services Company, Inc.

Contract NAS 9-15800

14 Power Extension Package Solar Cell Development

Funded by: Advanced Development (UPN-906)

Space Research and Technology Base (UPN-506)

Technical Monitor: J. L. Cioni/AT4

Task Performed by: Spectrolab

Contract NAS 9-16126

Applied Solar Energy Corporation

Contract NAS 9-16125

15 Power Extension Package Micro-Gravity Effects

Funded by: Advanced Programs (UPN-906)

Technical Monitor: J. C. Craig/AT4

Task Performed by: TRW

Contract NAS 9-15870

Lockheed Missiles and Space Company

Contract NAS 9-15595

16 Zero Prebreathe System

Funded by: Advanced Development (UPN-906-75)

Technical Monitor: M. Rodriguez/EC2

Task Performed by: Hamilton Standard

Contract NAS 9-15150

17 Piloting Aids for STS Proximity Operations

Funded by: Supporting Studies (UPN-906)

Technical Monitor: R. W. Becker/FM2

Task Performed by: TRW

Contract NAS 9-16275

18 Automated Rendezvous and Proximity Operations

Funded by: Supporting Studies (UPN-906)
Technical Monitor: R. W. Becker/FM2
Task Performed by: LINCOM Corporation
Contract NAS 9-16310

19 Space Operations Center Systems Analysis Study

Funded by: Major Systems Studies (UPN-906)
Technical Monitor: S. H. Nassiff/EB
Task Performed by: Boeing Aerospace Company
Contract NAS 9-16151
Rockwell International
Contract NAS 9-16153

20 Vapor Compression Distillation Urine Water Recovery

Funded by: Advanced Development (UPN-906)
Technical Monitor: C. D. Thompson/EC3
Task Performed by: Lyndon B. Johnson Space Center

21 Hyperventilation Wash Water Recovery System

Funded by: Advanced Development (UPN-906)
Technical Monitor: H. E. Winkler/EC3
Task Performed by: Carrie, Inc.
Contract NAS 9-16235

22 Ultra-Microwave Communications System

Funded by: Advanced Development (UPN-906)
Technical Monitor: J. S. Kelley/EE3
Task Performed by: McDonnell Douglas Astronautics Company
Contract NAS 9-15617

23 Space Construction Experiment Definition Study

Funded by: Major Systems Studies (UPN-906)
Technical Monitor: L. M. Jenkins/EB
Task Performed by: General Dynamics-Convair
Contract NAS 9-16303

24 Manned Geosynchronous Mission Requirements and Systems Analysis Study

Funded by: Major Systems Studies (UPN-906)
Technical Monitor: H. G. Patterson/EB
Task Performed by: Grumman Aerospace Corporation
Contract NAS 9-15779

25 A Geodetic Beam for Space Fabrication

Funded by: Advanced Programs (UPN-906)
Technical Monitor: T. J. Dunn/ES
Task Performed by: McDonnell Douglas Astronautics Company
Contract NAS 9-15678

Satellite Services System

The operational Space Transportation System (STS) will have onorbit satellite service capability using the Orbiter Remote Manipulator System (RMS) and extravehicular activity crewmember for (1) payload deployment and retrieval; (2) payload support on sortie missions; and (3) limited satellite support servicing within and/or adjacent to the cargo bay. The STS satellite servicing capability can be readily increased by the development of the proper servicing equipment items. Considerations include satellite user market, services needed for satellites, and servicing modes.

Anticipated capabilities include resupply of expendable items such as propellants, or raw materials for processing, checkout/maintenance and repair/replacement of components, reconfiguration of sensors, and component exchange.

Satellite mission models were developed to identify onorbit service concepts compatible with the satellite user community needs. The mission model data base was derived primarily from NASA, the Department of Defense and commercial mission plans, but data from available literature were also included. Emphasis was placed on Orbiter and near-Orbiter operations in the 1981 to 2000 time period. The approach used to develop satellite services concepts was to analyze servicing scenarios associated with the selected satellite mission models and then derive the appropriate service equipment requirements. The equipment selections were guided by the following groundrules: (1) attempt to standardize onorbit service operations; (2) maximize the use of existing equipment and those under development; and (3) enhance the utilization of the STS to the satellite user community.

Contracted and in-house studies have defined an overall plan for implementing a Satellite Services System and have identified the required servicing equipment. The plan is based on the timely development of "generic" types of service equipment that are essential for the majority of the anticipated service functions. The plan includes four equipment categories as follows:

1. Inherent equipment - Equipment that is inherent with the STS system, such as the Remote Manipulator System, extravehicular mobility unit, and manned maneuvering unit

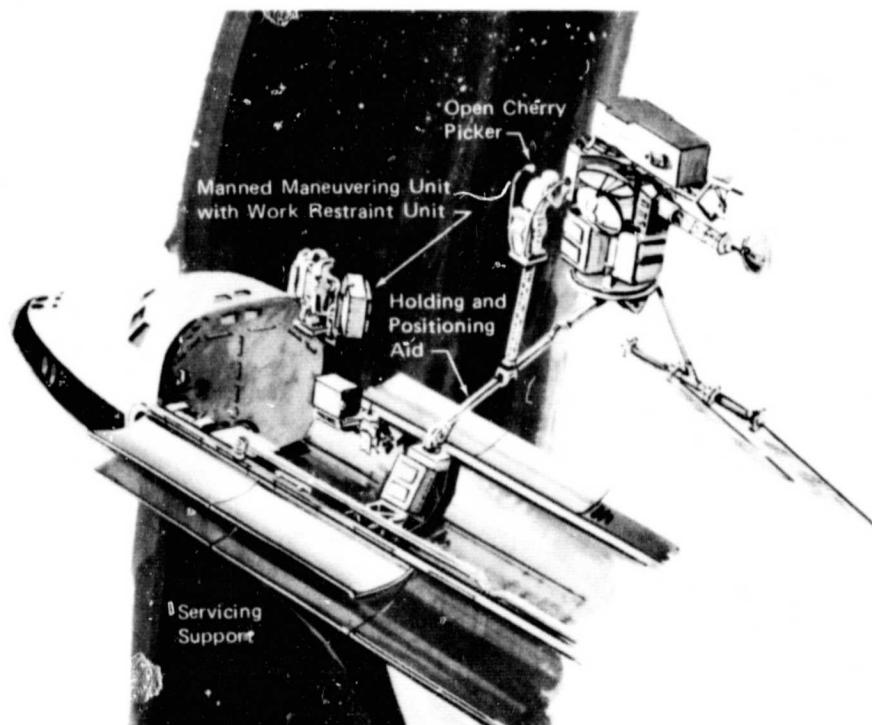
2. Generic equipment - Equipment which integrates with the inherent equipment and has growth potential, namely, the manipulator foot restraint/open cherrypicker, work restraint unit used in conjunction with the manned maneuvering unit, maneuverable television, holding and positioning aid, fluid transfer, and other tools

3. Unique equipment - Equipment unique to special mission requirements such as hand tools, equipment stowage, payload handling devices, and special purpose remote manipulator end effectors

4. Advanced equipment - Equipment potentially needed to fulfill future mission model requirements such as tow tug, sun shield, dexterous manipulators, lighting enhancement, and deorbit propulsion package.

Full-scale test models of the open cherrypicker, maneuverable television, and work restraint unit have been constructed and evaluated under simulated zero-gravity conditions. A detailed design of the holding and positioning aid has been completed and is available for the fabrication of a test model. Results of additional studies being conducted for the economic aspects of satellite servicing will be available in March 1982. Fiscal year 1982 studies will define the satellite design features and interfaces required for onorbit servicing.

Figure 1.— Servicing support



Manned Remote Work Station Development

A prime requirement is that the operational Space Shuttle will have the capacity to service satellites attached in the payload bay and detached in a free-flying mode. Studies have identified the specific hardware development necessary for the extravehicular activity (EVA) astronaut to increase orbital productivity for satellite servicing and maintenance, inspection, and for potential repair of the Orbiter. One identified need is to provide the astronaut with a stable platform from which he can perform a variety of work functions coupled with the capability to transport replacement modules to and from the Orbiter. The manned remote work station "open cherrypicker" (OCP) is a versatile system that can provide these capabilities. The cherrypicker is attached to the end of the Orbiter Remote Manipulator System, and both are controlled and operated by the EVA astronaut located on the OCP work platform. The cherrypicker will not only enhance Space Shuttle operations in the near term for satellite servicing, but it will also provide the capability to demonstrate techniques and operations that can be used to optimize construction of future large-system projects.

A program that includes development test articles has been formulated for evaluation and development of flight hardware requirements. This approach includes engineering simulations and testing on the JSC Weightless Environment Test Facility and Manipulator Development Facility. A simulation program has been developed and used to evaluate OCP systems and demonstrate satellite servicing. The OCP is shown servicing a satellite attached to the Orbiter payload bay in figure 1.

Two full-scale OCP test articles have been built for evaluation in the Grumman Aerospace Corporation Large Amplitude Space Simulator and the JSC facilities. During the Large Amplitude Space Simulator tests (fig. 2), the basic operational unit of the OCP known as the manipulator foot restraint, (MFR) has been evaluated. The MFR, proposed for early flights, consists of the strongback support structure, a rotatable standard foot restraint, and a rotatable handhold/tool caddy. Positioning of the MFR is controlled by the remote manipulator operator. The ancillary equipment, such as the payload handling device, can be added later to produce the fully operational OCP. The OCP/MFR test article will be integrated with the JSC Manipulator Development Facility in 1982 and used in simulations with the Shuttle Remote Manipulator on the air bearing floor. Possible future applications of the manned remote work station include closed pressurized cabin versions, railed work stations, and free-flying work stations.

Figure 1.— Open cherrypicker servicing.

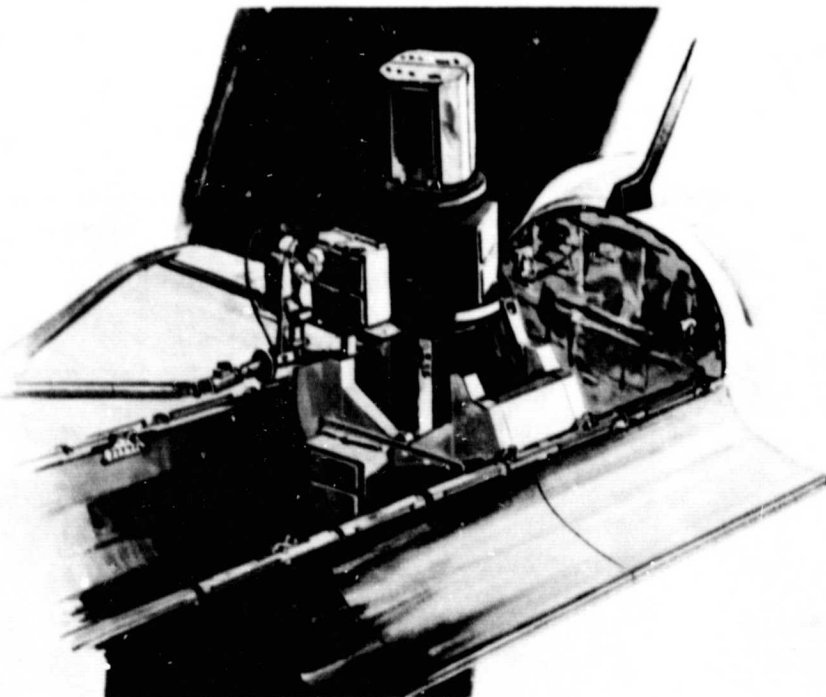


Figure 2.— Demonstration of satellite servicing with the MFR.

Maneuverable Television

The primary task of the Space Shuttle will be to carry payloads into orbit and service payloads that are in orbit. This function of satellite services encompasses many deployment and retrieval operations that will require specialized tools to assist the Orbiter in completing its mission. One identified need is the capability to remotely observe payload operations and to inspect satellites prior to final approach by the Orbiter. Another need will be to provide assistance to a small or unstable satellite to complement the retrieval by the Orbiter Remote Manipulator System. The Maneuverable Television (MTV) is under development at JSC to provide these capabilities in support of satellite services.

A study was initiated in fiscal year 1978 to identify the type of vehicle that could provide support to the Orbiter in close proximity when performing satellite services. The study defined a small subsatellite that will operate in the near field of the Orbiter having a full six-degrees-of-freedom and directed by a crewmember from the aft station of the Orbiter. The subsatellite, the Maneuverable Television, will function similarly to a remotely piloted vehicle. The MTV is remotely controlled by the Orbiter crew and, after undocking from the flight support station in the Orbiter payload bay, is directed to maneuver to the desired inspection or assistance point. The MTV is approximately 1 meter on each side, uses clean nitrogen gas for propellant, and carries several television cameras. Video of the object under observation along with telemetry information is transmitted to the Orbiter closed-circuit television system. The MTV provides its own battery power and lights for operating in nonilluminated areas. Figure 1 is an outline of the MTV and its subsystems. Subsystems were designed to utilize off-the-shelf hardware as much as possible. Figure 2 depicts a satellite inspection mission utilizing the MTV.

The efforts of fiscal years 1980 and 1981 resulted in the fabrication of a full-scale engineering model that will be operated on the JSC air-bearing facility. This model represents the end-to-end electronic systems, power

system, propulsion system, and docking system. Static testing of the electronic and mechanical systems of the MTV have been completed with satisfactory results. Dynamic testing on the JSC air-bearing facility will be

conducted during fiscal year 1982 to evaluate the performance with three degrees-of-freedom, to evaluate the crew/model interfaces, and the telemetry requirements.

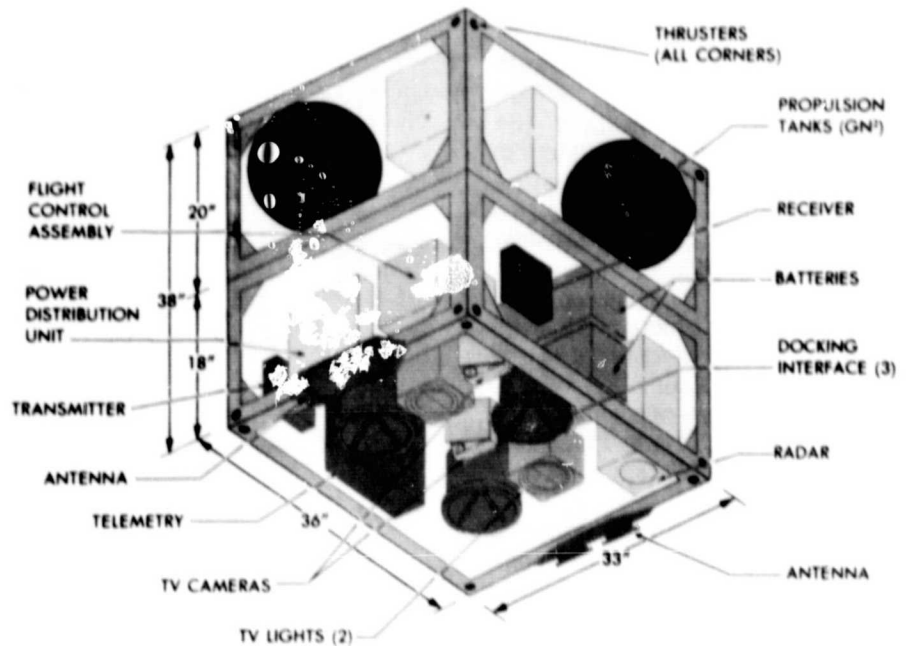
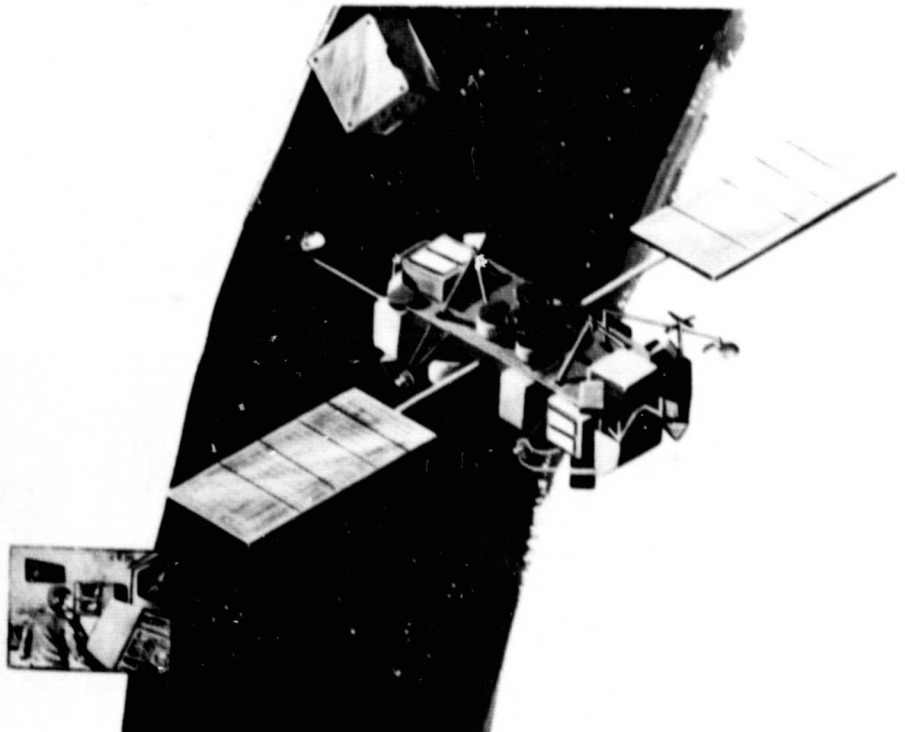


Figure 1.— The Maneuverable Television internal view.

Figure 2.— Satellite inspection by the Maneuverable Television.



Power Extension Package Solar Cell Development

The Power Extension Package (PEP) currently awaiting phase c/d initiation will require a large number of solar cells, more than any previous space project (fig. 1). The current cost of space solar cells, approximately \$100 per watt, is prohibitively expensive for a project of the magnitude of PEP. Studies conducted during the PEP activity at JSC have shown the possibility of reducing this cost to \$30 per watt. The cost reduction can be accomplished by increasing the size of the individual solar cells, simplifying the cell specifications, and increasing the in-line process control to reduce end-of-line destructive testing. The basic problem addressed in the PEP solar cell development activity is to determine whether or not the pursuit of these cost reduction techniques is appropriate for the PEP application.

The approach has been to conduct a two-phase program at two space solar cell suppliers, Applied Solar Energy Corp. and Spectrolab. The goal of phase I was to verify that large area solar cells can be fabricated to yield the same performance as the more conventional small solar cells. (See figure 2.) In addition, phase I was to determine if the large cells are applicable in the PEP array designs developed by TRW and Lockheed Missiles and Space Company.

Phase II, to begin in early FY-1982, will provide several thousand cells for qualification.

During 1981, both ASEC and Spectrolab completed phase I of the solar cell development program. Several hundred large-area solar cells were produced and tested by NASA and the array vendors. Candidate cell types were radiation-tested by Lewis Research Center to aid in the selection of a generic cell type for the PEP application. Solar cells produced during Phase I are also under evaluation at TRW and Lockheed Missiles and Space Company to determine if they are compatible with their particular array designs.

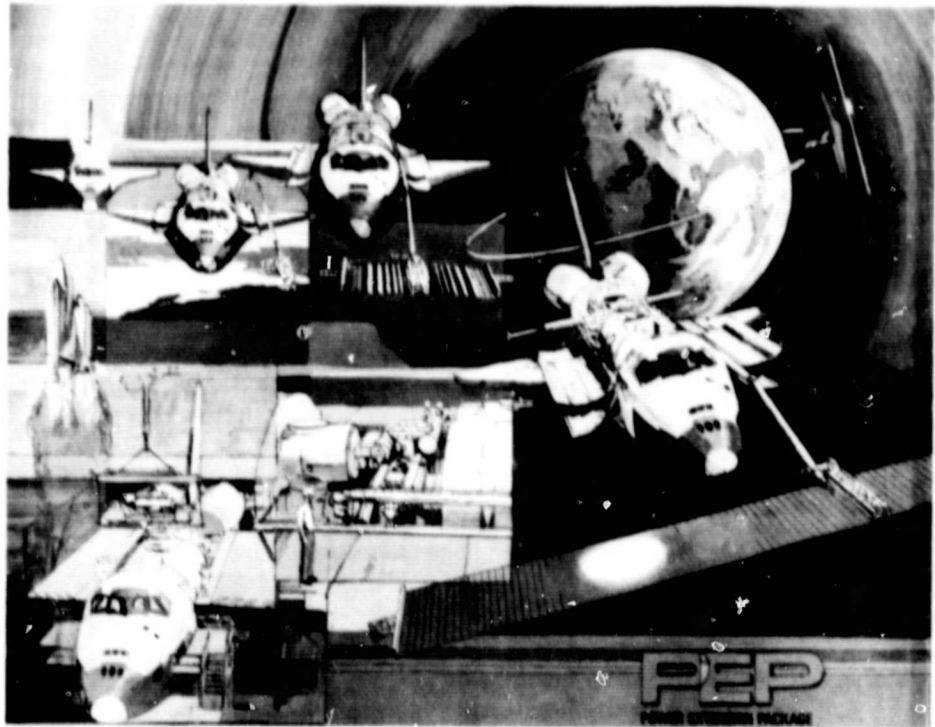
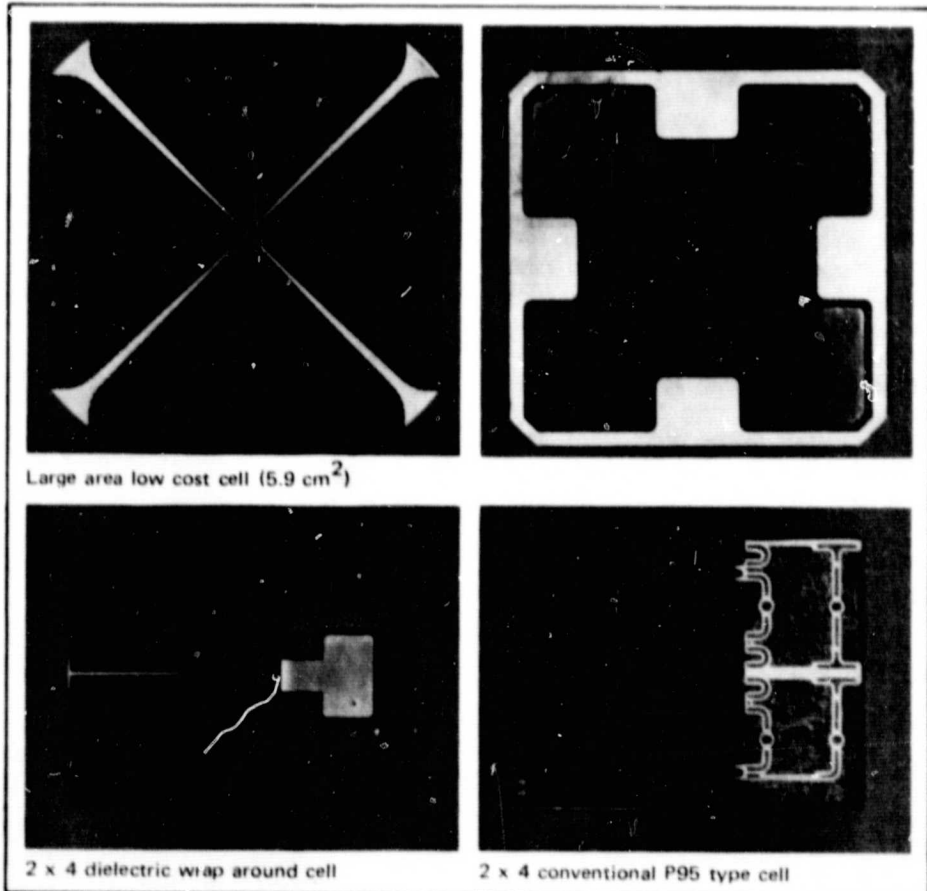


Figure 1 — Power Extension Package.

Figure 2 — Power Extension Package solar cell development.



Power Extension Package Micro-Gravity Effects

The Power Extension Package (PEP) shown in figure 1 is a mission kit designed to provide the Space Shuttle usage with added power and increased mission duration.

The dynamic environment in which the PEP solar array must exist is not purely zero gravity. Orbiter attitude corrections, maneuvers, and other operations produce various loads on the array assembly. In addition, the array must be capable of deployment, retraction, and Sun tracking under a wide variety of Orbiter mission requirements. The movements of the array and its various subassemblies, which are necessary to meet these requirements, present a number of unique design requirements. The design of the panel hinges, substrates, and guidewire system must provide support and control of the array blanket at all times to prevent damage of the solar cells and other components.

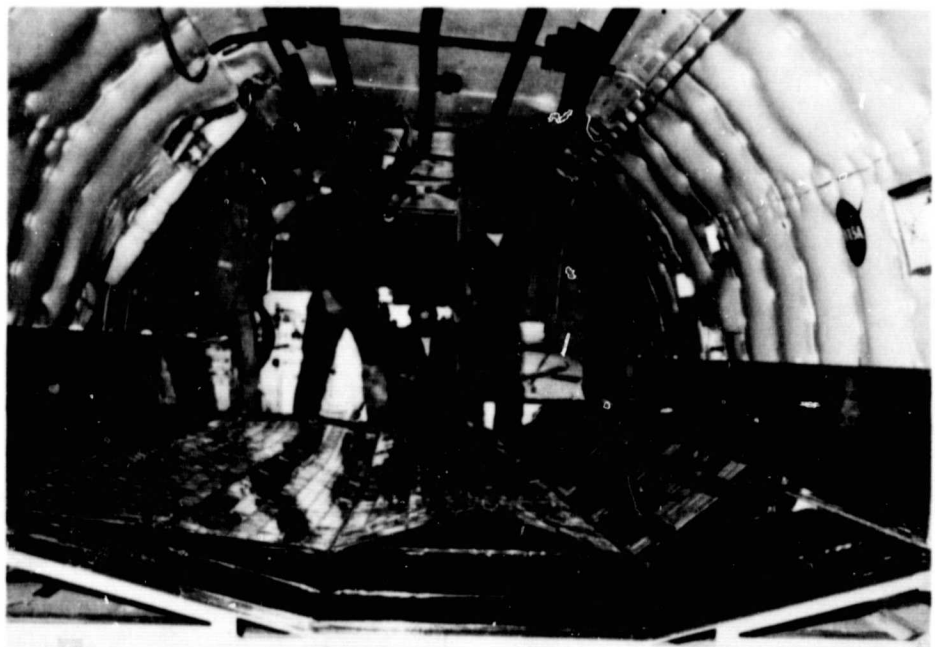
Test articles were built that represented the two basic array design concepts of TRW and Lockheed Missiles and Space Company. These test articles were flown in NASA's KC-135 aircraft and subjected to predetermined gravity levels ranging from 0 to 0.3 g. During the inflight testing, the array test articles were deployed and retracted to determine the sensitivity of the various design parameters to performance requirements. Various characteristics such as hinge and panel stiffness and guidewire tension and location were tested. Figure 2 shows the actual test configuration for the LMSC design.

Under the test conditions, both designs were shown to function satisfactorily at gravity levels of 0.2 to 0.3.

Figure 1.— Orbiter Power Extension Package.



Figure 2.— KC-135 micro-gravity test of LMSC baseline configuration.



Zero Prebreathe System

The current baseline in support of operational Shuttle Extravehicular Activities (EVA) requires that EVA be conducted at 4.1 psia from a 14.7-psia cabin. To preclude the "bends", a painful and potentially dangerous physiological condition resulting from bubble formation when dissolved nitrogen in body tissues is driven out of solution by exposure to reduced ambient pressure, Space Transportation System crewmembers prebreathe pure oxygen for 3 hours to denitrogenate prior to an EVA. However, the crew considers the Portable Oxygen System used for prebreathing excessively restrictive prior to Extravehicular Mobility Unit (EMU) donning. Additionally, denitrogenation can be significantly reduced by accidentally taking one or two breaths of air, considerably increasing the likelihood of bends.

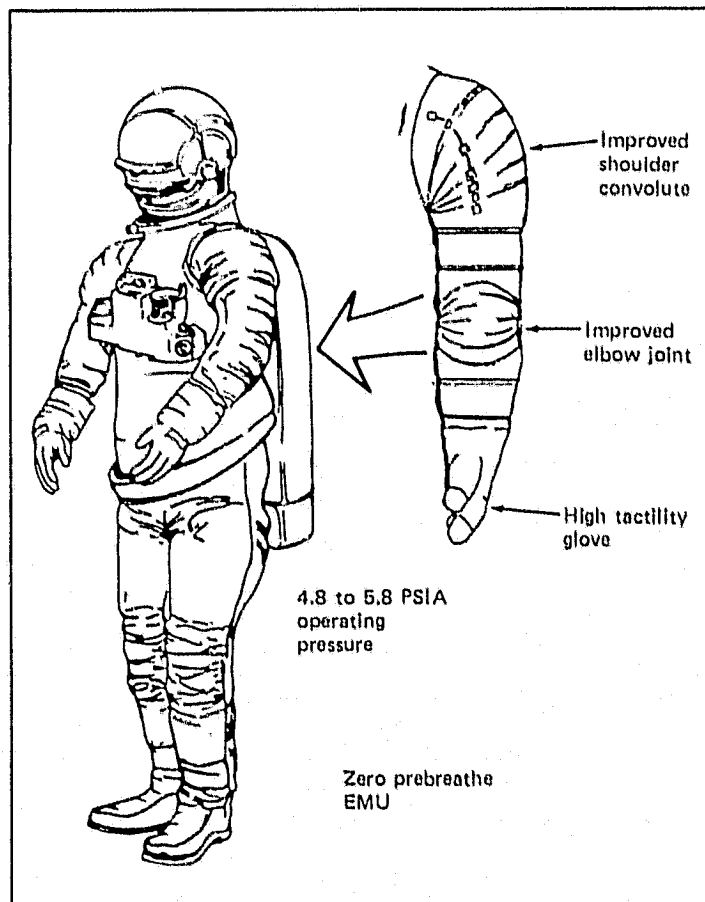
In order to avoid the encumbrances related to prebreathing, a study was instigated to establish how to best eliminate prebreathing with minimum hardware impacts. The variables that could be altered to effect the desired results were cabin pressure and EMU pressure.

Factors considered in the determination of a solution were life support system impacts associated with greater operating pressures, Orbiter impacts related to decreased cabin pressure, materials compatibilities at higher oxygen pressures, effects of pressure variations on payloads, and crewman physiological constraints.

The investigation of the relevant study issues defined an allowable pressure band for reduced cabin pressure and an increased EVA pressure band that together could eliminate prebreathing requirements. When Orbiter cabin pressures of 11.0 to 12.0 psia are properly balanced with EVA operating pressures of 4.8 to 5.8 psia, there will be no need for prebreathing prior to each EVA. However, it will be necessary for the crewman to equilibrate himself with the cabin atmosphere before the initial EVA. This can be accomplished as a function of time or by a short one-time prebreathing with 100 percent oxygen. However, the cabin oxygen partial pressure must always remain above the 4000-foot alveolar equivalent to avoid the effects of hypoxia.

A more detailed evaluation to determine the specific Orbiter and EMU impacts associated with different operating pressures is currently in progress so that the optimum Orbiter and EMU pressures can be selected.

Figure 1.— Zero prebreathe extravehicular mobility unit.



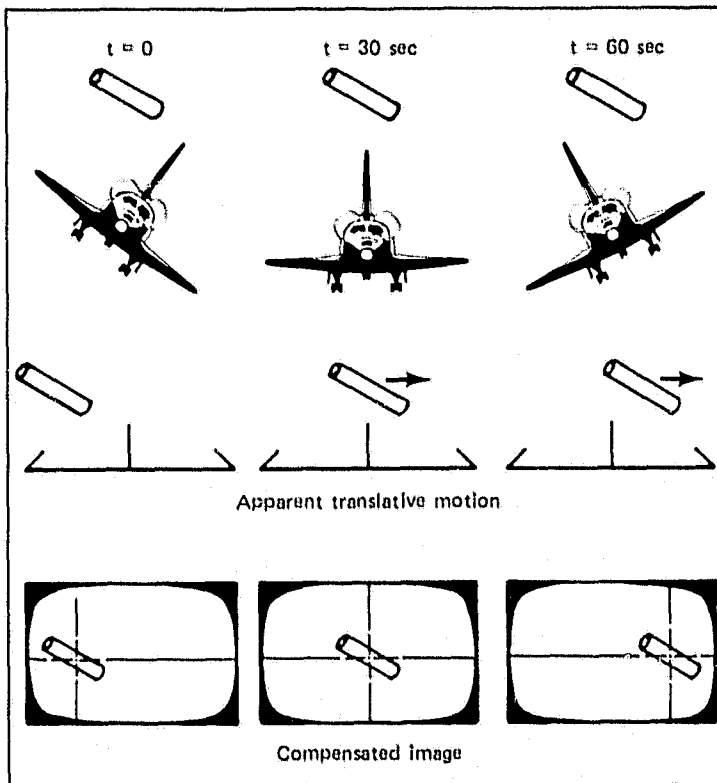
Piloting Aids for Space Transportation System Proximity Operations

During Shuttle Orbiter proximity operations such as stationkeeping it is difficult for the pilot to visually determine whether the apparent motion of a free-flying payload is "real" (requiring a translational correction on his part) or simply the result of the Orbiter's rotation. One solution is to set narrow deadbands for digital auto pilot attitude control, but this consumes Reaction Control System propellant and magnifies the problem of unwanted translational accelerations caused by uncoupled thrust from the attitude control jets.

The pilot's task can be made easier by superimposing a computer-generated reference pattern on a television image of the payload. In its simplest form, the Television Image Compensation (TIC) System generates cross hairs whose position and orientation are driven by guidance system — sensed attitude errors. To justify its development, it needs to be verified that TIC would significantly reduce pilot fatigue, propellant consumption, and stationkeeping position errors. Obtaining such data requires many hours of real-time man-in-the-loop simulation. Because of its low operating cost, the JSC Desk-Top Flight Simulator has been chosen as the tool for preliminary evaluation of TIC effectiveness.

The Desk-Top Flight Simulator (DTFS) has been modified to incorporate a conceptual model of the TIC system. The fidelity of the DTFS models of the environment, payload and Orbiter dynamics, and the digital autopilot/Reaction Control System have also been upgraded so that the TIC effectiveness data will be representative of on-orbit operations. An extensive series of real time simulations are scheduled during the next fiscal year. A spinoff of this initial effort is that the upgraded DTFS will be available for general use in the design and evaluation of Proximity Operations techniques.

Figure 1.— Television image compensation system.



Automated Rendezvous and Proximity Operations

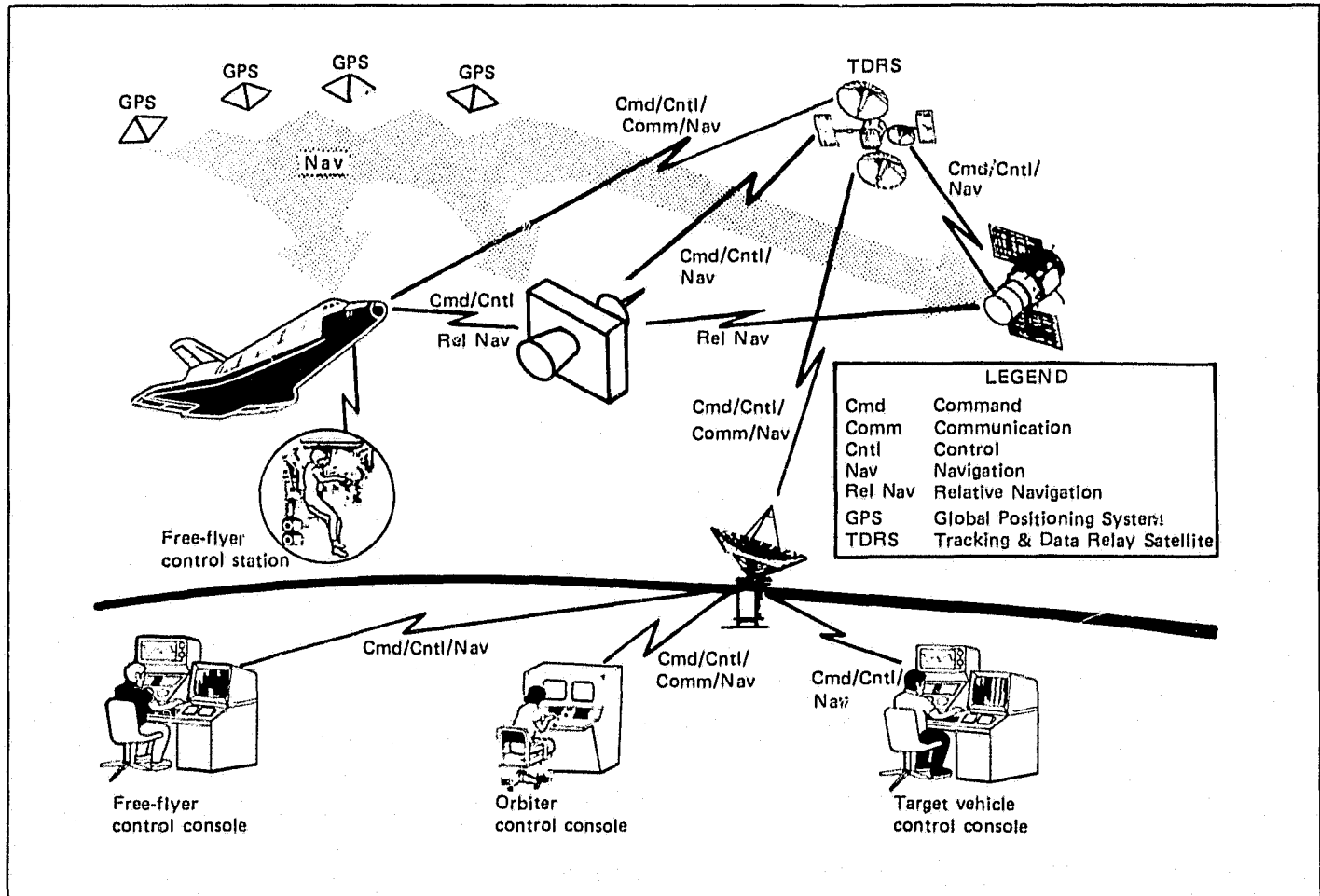
Future STS missions will require routine rendezvous with orbital objects for the purpose of servicing, docking, retrieval, or inspection. Many of these satellites requiring services will be in orbits not attainable by the Space Shuttle. Others will be obtainable only through use of expensive additional orbital maneuvering propellant kits.

A potential solution to this problem would be through the use of a Shuttle-based free-flying satellite. The solution approach includes the analyses of hardware, software, and operational requirements for "free-flyer", rendezvous, and proximity operations. The definition of generic automated rendezvous missions is necessary for considering scenarios, system concepts, and existing documentation.

From a subset of these candidate missions, detailed analyses will be performed to develop operational techniques and flight profiles to meet the known and assumed satellite requirements. The results will be used to delineate specific requirements for hardware systems, software systems, profiles, and procedures.

Results, to date, include the near completion of the generic mission definition phase, startup of the selection and evaluation of the candidate mission subset and a continuing effort to integrate the NASA technical activities relating to automated rendezvous and proximity operations.

Figure 1.—Automated Rendezvous Command and Control System.



Space Operations Center System Analysis Study

The first true Space Transportation System that introduces reusability and operational flexibility has been demonstrated by the first successful flight of the Space Shuttle. During the 1980's, subsequent Space Shuttle flights will be used for routine on-orbit placement and retrieval of satellites. Spacelab modules and pallets will extend the capability to conduct scientific and engineering operations. The Shuttle will also be used for satellite maintenance and repair and to develop methods of space construction for various operational systems. Many mission payload concepts now being proposed are large, complex space systems that require on-orbit capabilities for deployment, assembly, and construction which will severely tax the capability of the Space Shuttle. The logical next step in manned space flight is the creation of permanent manned operational presence in space to expand our capabilities for space operations beyond that practical with the Space Shuttle. The Space Operations Center (SOC) has been proposed as the operational orbital facility to satisfy these needs. The Space Shuttle will compliment SOC operations by providing SOC assembly and buildup, logistic supply flights, crew rotation and rescue capability.

The initial phase of the SOC System Analysis Study performed by Boeing Aerospace Company was completed in July 1981. The 12-month study provided concepts for growth SOC configurations, including mission model, subsystem requirements, and associated development costs and schedule. SOC technology identification was provided that will be incorporated into an overall technology development plan. A companion SOC/Shuttle interaction study by Rockwell International was completed in March 1981. It addressed the issues of Orbiter Docking/Berthing with SOC, SOC assembly and buildup, propellant transfer, and SOC flight support facility requirements. Both contracts have been extended for 5 months for further refinement of SOC support of the Space Transportation System goals.

The contract extensions will further analyze flight support facility handling and servicing requirements for upper stages, SOC/Shuttle Assembly Operations, Shuttle Fleet Utilization, methods for Shuttle propellant scavenging and transfer, mission requirements and configuration updates. These analyses are required to reduce cost and schedule uncertainties prior to initiating future development activities.

Figure 1 shows a possible initial four-man SOC configuration comprised of a service module, habitation module, and logistics module. Figure 2 shows an eight-man configuration and how mission needs are accommodated by the addition of a service module, habitation module, construction support equipment, and flight support facility for Orbiter Transfer Vehicles.

Figure 1.— Four-man SOC configuration.

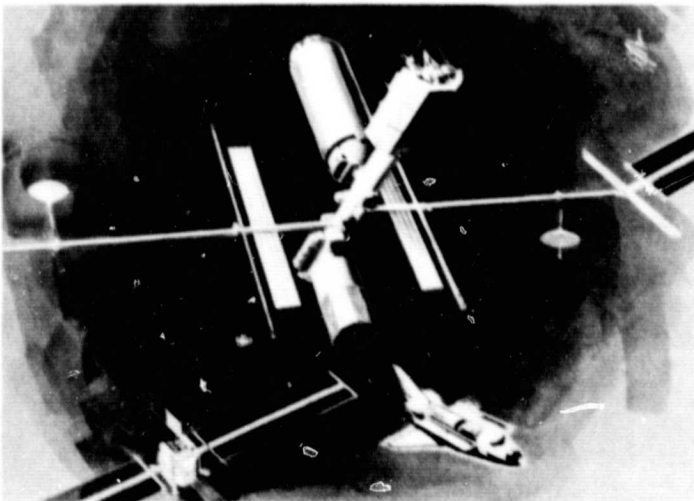
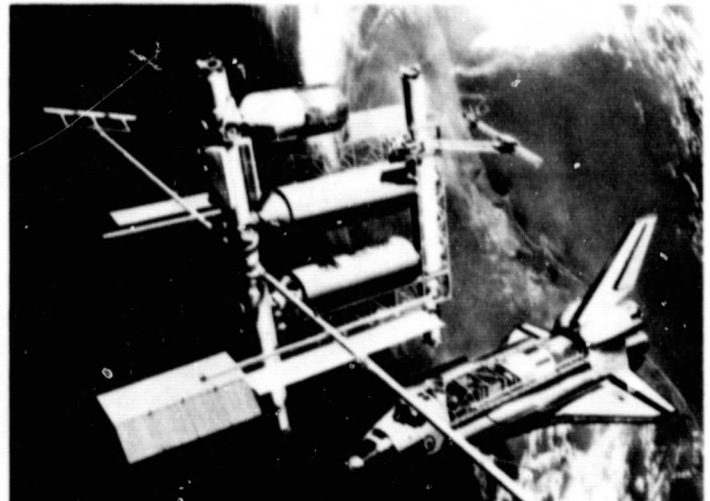


Figure 2.— Eight-man SOC configuration.



Vapor Compression Distillation Urine Water Recovery

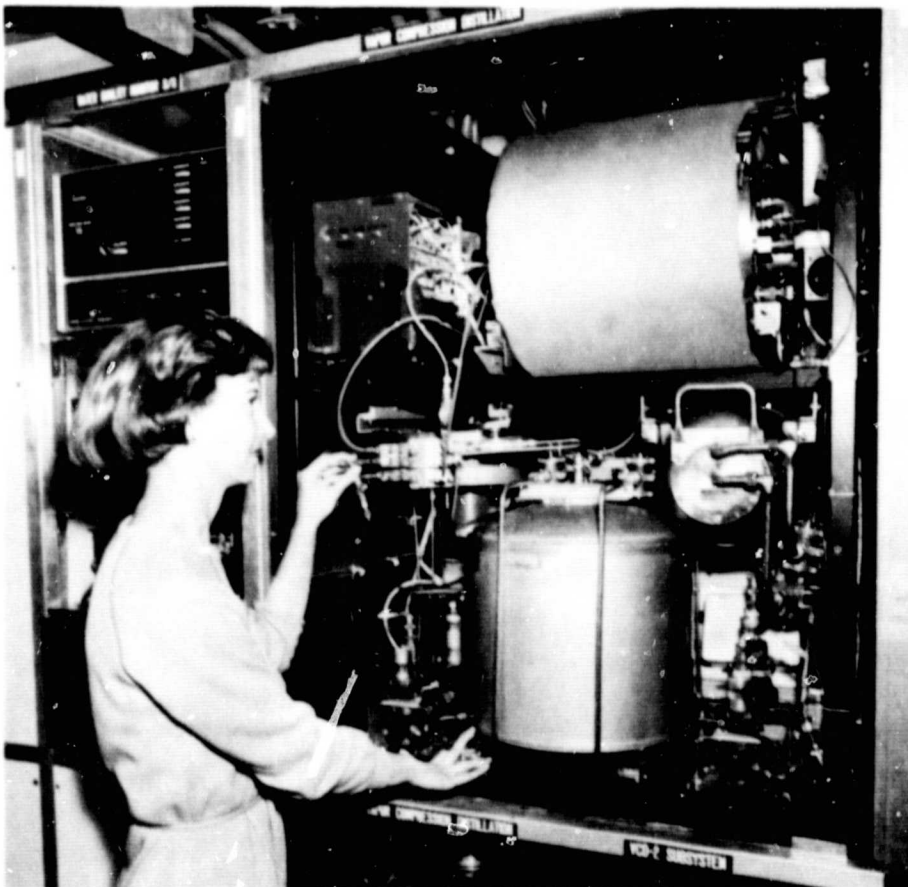
As manned mission requirements increase (i.e., larger crew size, longer onorbit stay time, higher power usage), the need for inflight water recovery will become acute. This will be particularly true as solar power replaces fuel cells as the primary vehicle power source, as planned for the Space Operations Center. Water for drinking and evaporative cooling previously produced by the fuel cells must then be supplied either from stored water (resupplied by Shuttle) or from water recovered from crew urine, humidity condensate, and wash water. Trade-off studies indicate that water recovery can be justified for Space Shuttle missions longer than 50 man-days and is the only practical option for missions aimed at providing a permanent manned presence in space such as the Space Operations Center.

A phase-change process, Vapor Compression Distillation, has been demonstrated to be the most efficient and technically mature process for recovering potable water from urine and flush water. The basic Vapor Compression Distillation process involves the reduced-pressure evaporation of water from a feedstock of treated urine, followed by compression and condensation of the water vapor. Evaporation and condensation occur on opposite surfaces of a rotating cylinder, allowing the transfer of the latent heat of condensation back to the evaporator, thus making the process highly energy efficient. No heat input is required by the system other than that provided by friction and the mechanical work done by the compressor in transporting the water vapor. The cylinder is rotated to provide an artificial gravity field. The process has been automated and adapted for Space Operations Center application and has progressed through several developmental stages.

Two Vapor Compression Distillation subsystems of preprototype design are undergoing extensive test programs in the Advanced Life Support Development Laboratory at the Johnson Space Center. One subsystem has completed 1800 hours of testing while processing over 3700 pounds of urine feedstock. The test program has demonstrated a water recovery efficiency of 96 percent and a low specific energy of 55 watt-hours per pound of water recovered. As many as 19 consecutive days of testing were accumulated without a subsystem problem requiring shutdown. This particular subsystem currently is being modified for evaluation of design improvements identified during the development test program and will be used to evaluate the integration of water and air-recovery systems. The second subsystem has completed 145 hours of a 1200-hour endurance test, which is currently underway. A water recovery efficiency of 96 percent is presently being obtained.

The preprototype test program has identified and incorporated many improvements in design concepts and materials that will lead to increased component life and system reliability. Testing in 1982 will continue with the evaluation of these design improvements and assessing the ability of the vapor compression distillation process to recover water from a wash water feedstock. Analysis of recovered water has verified that only limited post-treatment steps are needed to meet potable water quality standards.

Figure 1.— Vapor compression distillation process.



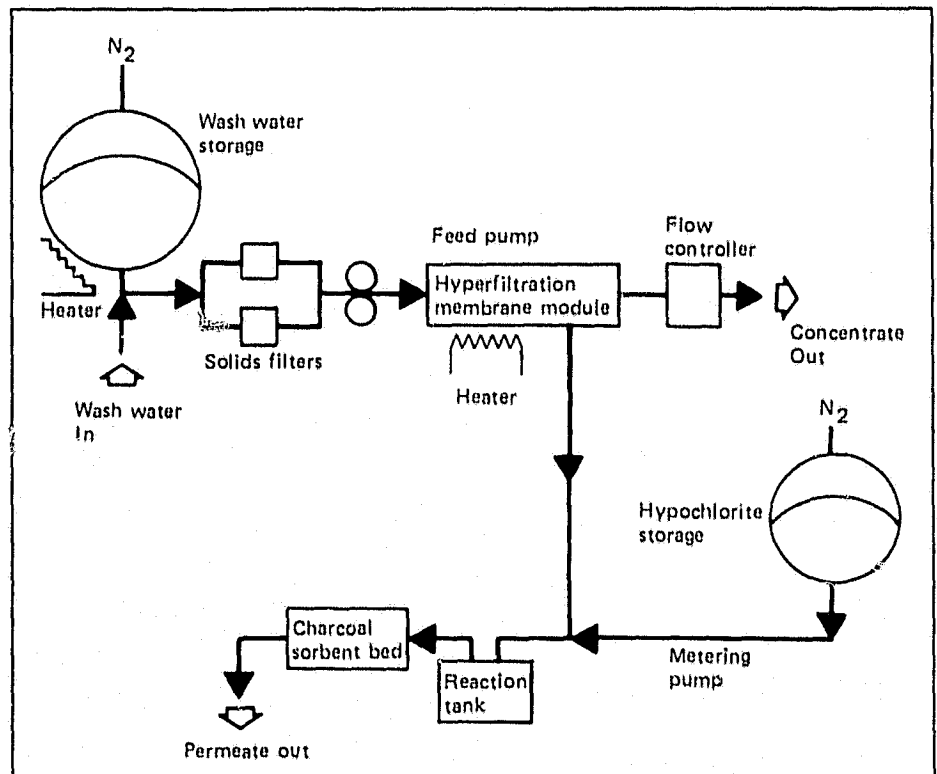
Hyperfiltration Wash Water Recovery System

Spacecraft that will provide for a permanent manned presence in space, such as the Space Operations Center, will probably include a shower and handwash for crew hygiene, and possibly laundry and dishwater facilities. For an 8-man system with these features, over 400 pounds of wash water would be required each day. On-orbit reclamation of wash water would be mandatory to minimize the makeup water supplied by the Space Shuttle.

Hyperfiltration is a pressure-driven osmotic separation process employing a semipermeable membrane which selectively permeates nearly-pure water while rejecting suspended and dissolved species at the membrane surface. A module containing a dynamically formed membrane represents the heart of the hyperfiltration wash water subsystem. Dynamically formed membranes are characterized by high permeate fluxes and moderate solute rejection levels. The dual-layers of the membrane, polyacrylic acid over zirconium oxide, are deposited on porous stainless steel tubes. Wash water feedstock at pasteurization temperature (165° F) is batch processed using a single pass design. At a system pressure of 1000 psia and feed velocity of 2 feet per second, the membrane module provides a water recovery rate of 90 percent. Permeation through the membrane is inversely proportional to the molecular size of the solute in the feed. Urea and ammonia are removed by adding sodium hypochlorite to the permeate downstream of the module. The concentrated brine from the module is further processed along with the urine in the vapor compression distillation subsystem.

A preprototype Hyperfiltration subsystem capable of processing the wash water from a shower and laundry for a crew of six persons is currently undergoing extensive checkout and parametric testing. An improved hyperfiltration module, which contains a single 200-foot long porous stainless steel tube will be evaluated with the subsystem.

Figure 1.— Hyperfiltration Wash Water Recovery System.



Ultra-Microwave Communications System

The Space Transportation System (Space Shuttle) has the capability to revolutionize space operations. In the very near future, payloads can be economically and routinely carried to and from low Earth orbit. Full exploitation of this capability will require a similar revolution in space communications. Many space-to-space communications links will be required, and several of the links will be needed to carry massive data rates. For example, the Space Operations Center (SOC) is projected to require wide band (high data rate) communications links to several Free-Flyers in addition to medium bandwidth links to several Orbital Transfer Vehicles (OTV). Similar communications requirements can be envisioned for large space construction experiments and eventually in actual space construction and industrialization.

The vast communication requirements must be accommodated while maintaining freedom from interference among themselves, with Earth communications, and with Earth-satellite communications.

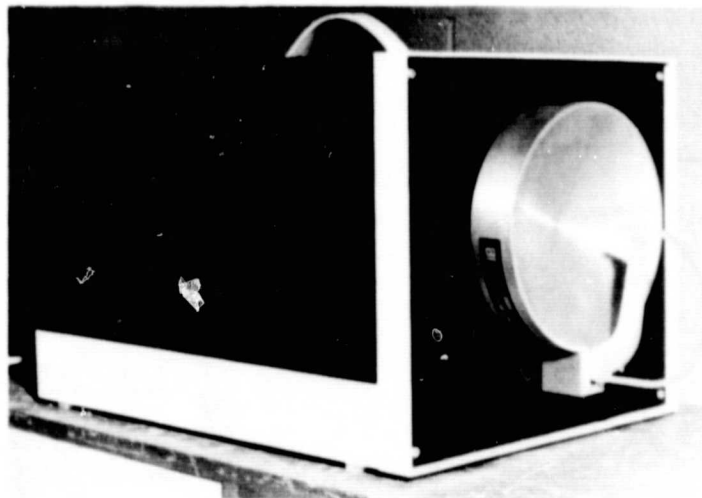
The frequency spectrum from 100 to 200 gigahertz holds enormous promise for fulfilling these requirements. The bandwidths (data rates) are conceptually almost unlimited; small antennas produce narrow beam radiation patterns which help in spacial isolation; many carrier frequencies can be assigned to obtain frequency isolation; frequencies can be selected for high atmospheric attenuation, thus, providing isolation from Earth-communication links and from Earth-satellite links.

This communications problem was approached from the aspect of "system development". The aim was to determine if component and device technology was available to support the design and assembly of a communications system at these frequencies. In the absence of adequate component technology, particular areas of component development requirements would be pinpointed. A systems-oriented contractor was selected to perform the required research project. It was determined that, while laboratory devices and subassemblies were available at several frequencies in this band, adequate component technology was available only at the low end. Therefore, 105 gigahertz was selected for the system design. The system was designed to transmit digital data with a 1.2C megahertz bandwidth.

A wide band, 105 gigahertz, communications system was successfully designed and assembled. Two 5-megahertz television signals have been successfully transmitted in a laboratory bench test. Additional testing will be completed at JSC later this year. While a lab model communications system has been successfully assembled and is operating quite well, it was determined that adequate component and subassembly technology is not now available in the 100-gigahertz and above frequency range. Reliability is an unknown at these frequencies because of the very limited number of devices that are being fabricated and tested. It was also determined, due primarily to small numbers, that repeatability (in this case conformance to vendor specifications) is very poor. External isolators and tuners were required extensively to make the system work, and the prime oscillator stability is such that frequent adjustment of its frequency is required.

The lack of subassembly integration at this time makes it impossible to take advantage of the potential small packaging which this frequency range should provide. The basic devices and components are available to provide wideband communications at the 100-gigahertz frequencies. However, exploitation of this potential requires additional development in the areas of device reliability, subassembly integration, and subassembly performance repeatability.

Figure 1.— Prototype 105-gigahertz receiver.



Space Construction Experiment Definition Study

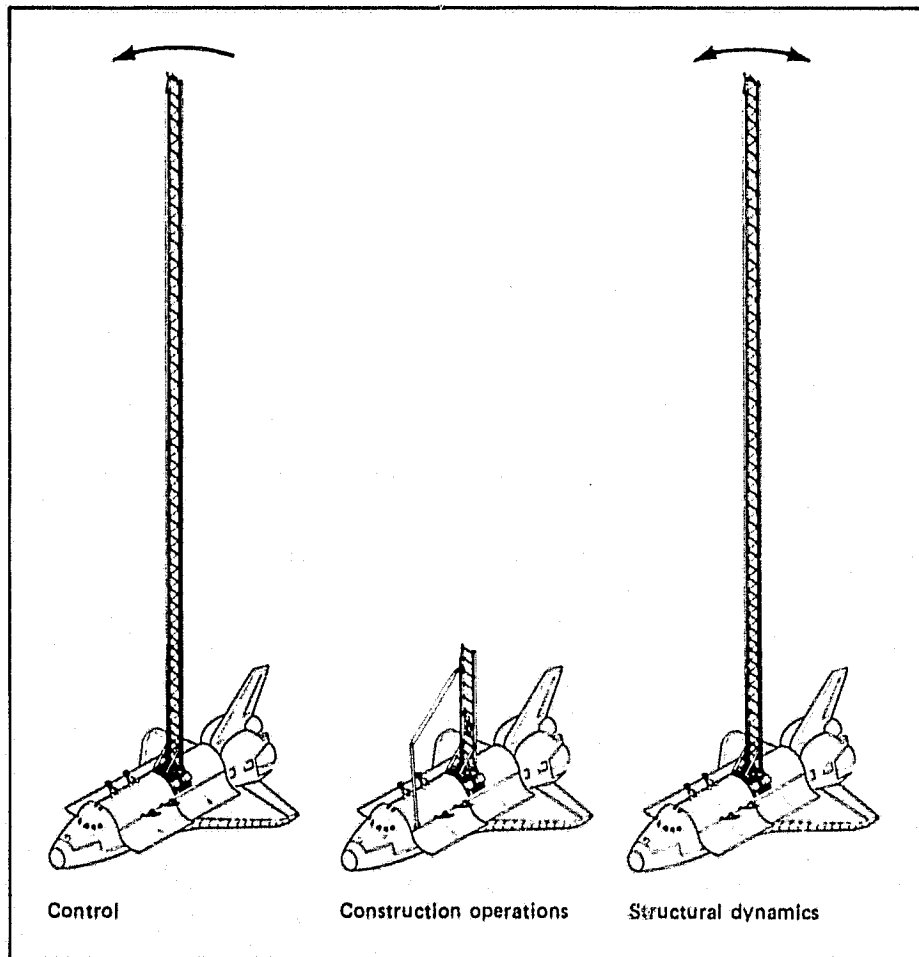
Future space program plans include spacecraft with size and weight that exceeds the Space Shuttle single-launch capability. Implementation of any of these programs will require the capability to assemble or construct large systems in space. Although such construction would eventually be the function of a Space Operations Center, the initial space construction projects must be assembled from the Orbiter. Before the ability to construct or assemble large space systems has been demonstrated, users will be reluctant to employ large space structures concepts. An appropriate construction experiment can provide significant data bearing on the cost and risks of space construction. Several complex and ambitious demonstration projects have been studied. Generally, these demonstration projects have not integrated desired objectives into a simple flight experiment of a practical size and cost.

The problem has been approached in a study to define an Orbiter-based flight experiment that will provide fundamental data on construction in space and the potential to evolve into a series of experiments related to construction issues. The experiment objectives address three principal issues: dynamic characteristics of a typical deployable structure, construction operations, and structure/control interaction. The experiment would be focused on a typical deployable structure that represents the dynamics of a low-frequency structure in space. Construction operations would evaluate and demonstrate fundamental Shuttle capabilities involving the Remote Manipulator System and the crew extravehicular activity (EVA). The ability of the Shuttle digital auto pilot to control a large low-frequency structure attached to the Orbiter would be evaluated.

The initial phase of the study has been completed with the preliminary design of a basic flight experiment. During this phase, there were trades and evaluation of experiment concepts and construction issues. Ten candidate deployable structures were evaluated resulting in the selection of a diamond truss configuration. The selected truss material was a graphite fiber/epoxy matrix to reduce thermal interactions. The basic experiment concept is a beam deployment from a support structure in the cargo bay. The deployment is incremental to permit evaluation of the digital auto pilot performance in a safe manner. The Remote Manipulator System and EVA are used to aid in the deployment and to attach equipment modules.

Computer simulation of the configuration uncovered an interaction with the digital auto pilot state estimator filter that will be examined in greater detail during phase 2 of the study.

Figure 1.— Beam deployment from cargo bay support structure.



Manned Geosynchronous Mission Requirements and Systems Analysis Study

The success of the first Orbiter flight heralds the start of a new era in which manned missions to low Earth orbit will be commonplace. The extension of regular manned operations to other high energy orbits, including geosynchronous, is a logical extension of this capability. Activities potentially requiring manned participation in both low Earth orbit and geosynchronous Earth orbit consist of construction, inspection, servicing, repairing, and operation of large space systems such as communications, solar power, and Earth observation satellites. To exploit the capabilities of the Space Transportation System and to develop the full potential of space operations, it is essential that development planning of Orbital Transfer Vehicles be expanded to include manned capability.

The main objective of this effort is to establish mission and systems opportunities and capability options for various levels of manned activity requirements, and to synthesize crew module and/or other manned system support necessary for extension of manned mission capability to geosynchronous orbit. This study emphasizes manned geosynchronous orbit sortie missions and associated crew system components.

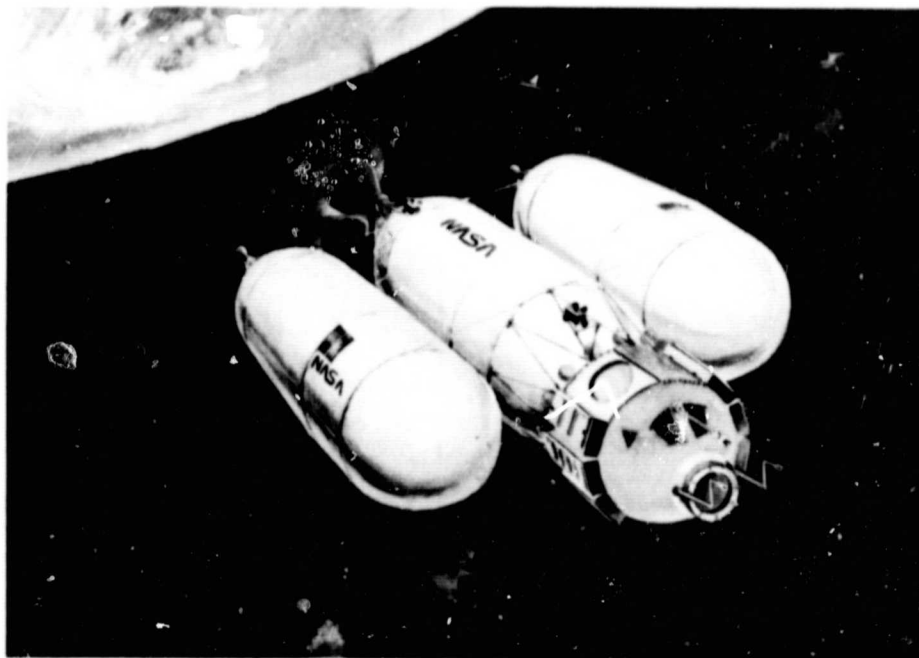
In Phase 1 of the study, a broad range of generic missions was selected from which manned Orbital Transfer Vehicle (MOTV) requirements were derived. These missions were divided into five categories as follows: inspection, service, and repair; operation of a large space system; debris removal; construction; and unmanned cargo transport. The missions range from short duration, low weight to long duration missions with heavy mission-hardware weight to orbit. The main objective was to develop a versatile MOTV concept that would encompass most of these generic missions with a minimum of modifications. The concept that was selected was an all-propulsive MOTV using a 1-1/2-stage propulsion system and a 25.0-cubic meter crew capsule.

In phase 2 of the study, a communications satellite servicing mission was selected as the design reference

mission. In this mission, four communications satellites, all using the standard Multimission Modular Spacecraft (MMS) for subsystem support functions, are routinely serviced by the MOTV. The satellites are assumed to be located 90° apart in geosynchronous Earth orbit. Periodically, the MOTV visits each of these satellites and services the MMS subsystems.

The primary focus of phase 3 was centered on the selection of a preferred MOTV configuration and mission mode to perform the generic missions identified in the main study. Twenty generic missions were originally defined for MOTV but, to simplify the selection process, five of these missions were selected as typical and used as additional Design Reference Missions. Systems and subsystems requirements were reexamined and sensitivity analyses performed to determine optimum point designs. Turn-around modes were considered to determine the most effective combination of ground-based and space-based activities. With these inputs, a preferred concept for the crew capsule and for the mission mode was developed. Figure 1 depicts the selected vehicle and shows the 1-1/2-stage propulsion system and the "functional minimum" crew capsule.

Figure 1.— Manned Orbital Transfer Vehicle with 1-1/2 stage propulsion system and "functional minimum" crew capsule.



Significant results related to the crew cabin design are as follows:

1. Two-man crews and a mission of up to 30 days duration will accomplish 85 percent of the Orbiter Transfer Vehicle missions.

2. A two-man geosynchronous Earth orbit sortie mission will require a total weight of approximately 5000 kilograms, including 500 kilograms of up and back dedicated cargo.

3. A capsule length of 3.5 meters and a diameter of 3 meters allows mission equipment to be mounted externally and is compatible with the Space Transportation System cargo bay.

4. Radiation protection requirements indicate that the capsule wall should be approximately 1.1-centimeters of aluminum equivalent thickness.

5. Protection against solar proton storms will require return to an orbit of 3-Earth radii or less for events of sufficient magnitude.

6. A single-deck crew module is preferred over a two-deck crew module for crew habitability.

7. Accommodations for a two-crewmember, 30-day mission can be adequately provided by a crew capsule that has a free volume of 3 cubic meters for each crewmember.

8. Internal operation is preferred for routine service and repair tasks with extravehicular activity capability for emergency and contingency operations.

A Geodetic Beam for Space Fabrication

Large stationary structures in space will require very low density structural members because loadings are expected to be relatively low. However, attitude and configuration control requirements are expected to demand that the structures be highly rigid and inert to thermal distortion. Studies have shown that it is more cost effective to fabricate large numbers of very low density structural members in orbit rather than transporting Earth-fabricated members from Earth. For this to be feasible, it is necessary that the structure be simple, efficient, and require very little time and energy to fabricate.

JSC has adopted a geodetic approach to automated beam fabrication. Coils of composite wires are loaded into a beam-fabrication machine that deploys the wires in longitudinal and opposing helical patterns and joins the wires together at their cross-over node points to form a cylindrical beam having a triangular gridwork surface. The machine should require a relatively small amount of power, mostly consumed by the node joint encapsulation system. The wire material is a composite consisting of materials having positive and negative coefficients of thermal expansion proportionally mixed so that the wire has a zero coefficient of thermal expansion.

The beam fabrication machine concept and geodetic beam structural feasibility were developed in FY-1978. In FY-1980, engineering design and analyses, material properties, and parametrical test data were developed as well as a beam-end-closure demonstration article. A complete beam having a length-to-diameter ratio of 10 will be fabricated using a graphite/plastic composite wire (fig. 1). A demonstration beam segment made with a graphite/metal composite wire will be fabricated. Figure 2 shows the geodetic beam end closure and cylinder test structure successfully compression-tested to $P = 2000$ pounds.

Figure 1.— Geodetic verification test beam.

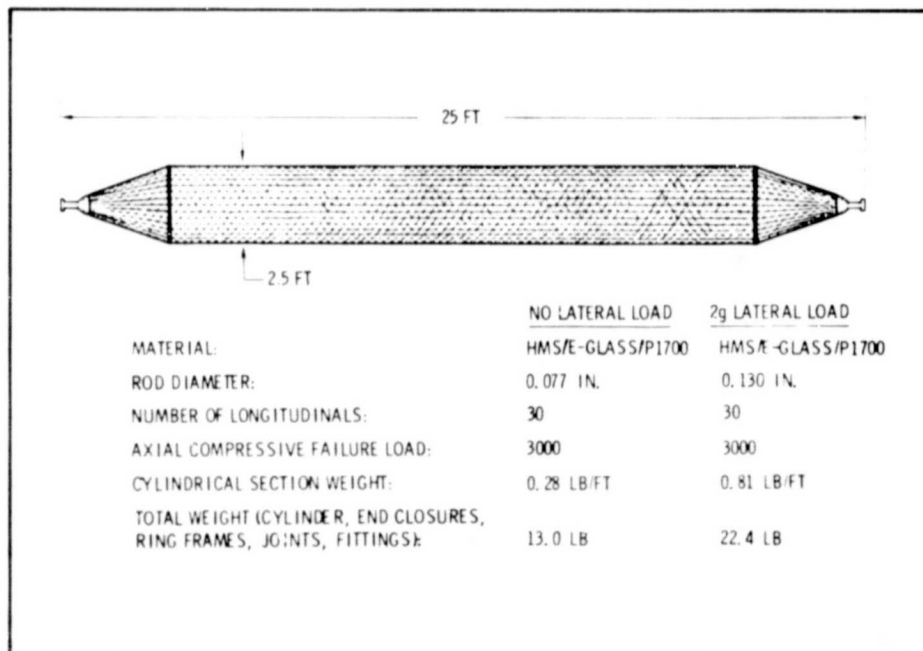
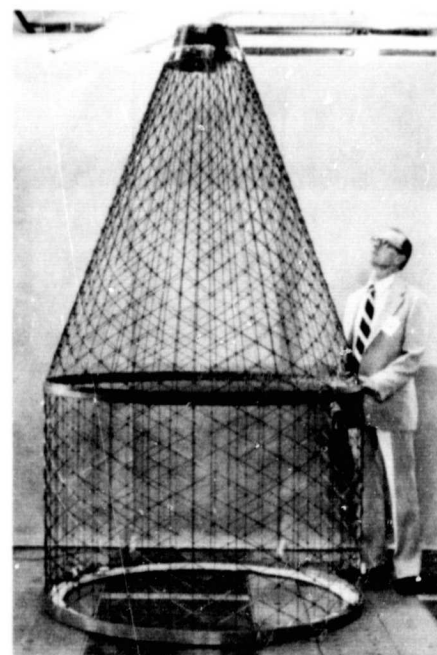


Figure 2.— Geodetic beam end closure and cylinder test structure.



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Aeronautics and Space Technology

Office of Aeronautics and Space Technology

The activities at Johnson Space Center (JSC) funded by the Office of Aeronautics and Space Technology (OAST) involve aeronautical, space, and energy research and technology development. These research and technology areas encompass future developments of all NASA program offices as well as other Government agencies. The use of the Space Shuttle Orbiter as an experimental vehicle, the electrolysis cell/fuel cell orbital energy storage systems, the advanced onboard propulsion technology and the large space systems technology are areas of continuing JSC interest and activity.

The major activities in space research and technology at JSC during fiscal year 1981 were (1) support to the Orbiter Experiments Program for which JSC continues to provide overall integration management and program planning, technical development for specific experiments (including development of supporting equipment), and integration of experiments into the Orbiter; (2) large-capacity orbital energy storage systems research and technology, which include fuel cell development, development of advanced thermal management systems for space use, laboratory modeling of space plasma environmental interactions of large high-voltage solar arrays in the large vacuum chamber, and development of a large area, low-cost solar cell array for use with the Shuttle Orbiter Power Extension Package and other spacecraft using solar arrays; (3) advanced onboard propulsion technology; (4) multifunction synthetic aperture radar; (5) large space systems technology to lower cost of space assembly, fabrication, deployment, or servicing of large space systems; (6) concept definition of a Shuttle Launched Research Vehicle (SLRV) to support the OAST research programs in advanced space transportation systems and planetary research

Summary

technology; and (7) research in materials that includes the design and fabrication of a carbon-carbon stand-off panel to replace the Orbiter reusable surface insulation between the nose cap and nose landing gear door, research on the separation of mineral concentrates from lunar materials, and continuing research on fire resistant materials with low toxic emissions for aircraft/spacecraft use.

Experimental Programs

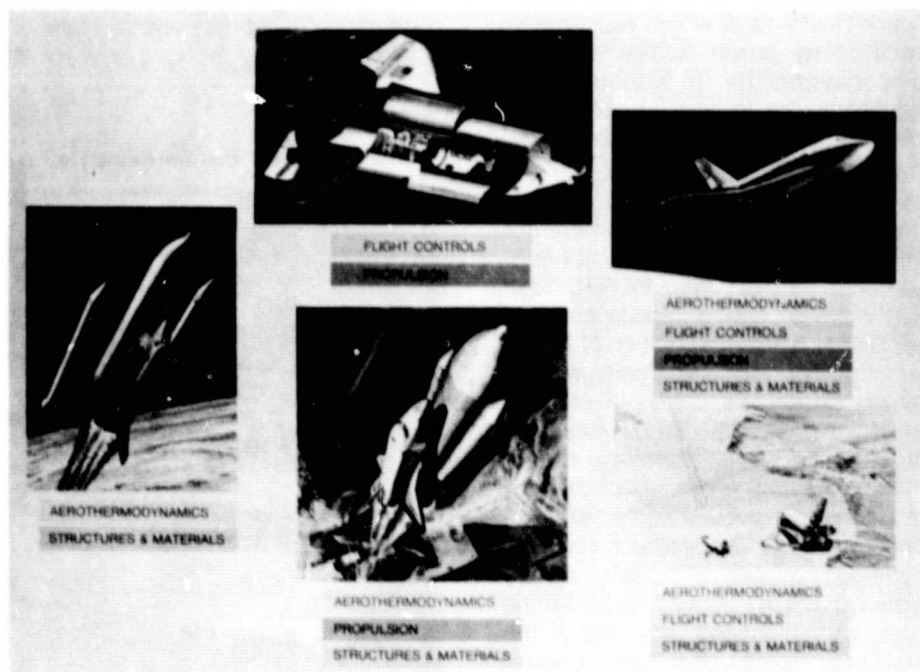
The Orbiter Experiments Program uses the Space Shuttle Orbiter as a flight research vehicle to obtain inflight data over a broad flight spectrum for a variety of technology disciplines (fig. 1). As the lead center for the over-all project, JSC is responsible for project management and integration of various Orbiter experiments. These ex-

periments are designed to augment the research and technology data base for design verification of current and future vehicles by collecting Shuttle flight data in related technology disciplines and to verify, correlate, and extrapolate data derived from ground-based facilities with the flight data. The Aerodynamic Coefficient Identification Package (ACIP) experiment was successfully flown on STS-1.

Integrated Orbital Energy System

Advances in critical space power research and technology at JSC in fiscal year 1981 include (1) low-cost, large area solar cells in support of the Orbiter Power Extension Package, (2) high-capacity energy storage based on the Solid Polymer Electrolyte membrane fuel cell, (3) thermal management of onorbit energy systems,

Figure 1.— Shuttle mission experiment opportunities.



and (4) modeling of space plasma environmental interaction of large, high-voltage solar arrays.

The development of the large area solar cell is jointly sponsored by the Office of Aeronautics and Space Technology (OAST) — through a subauthorization from Lewis Research Center — and the Office of Space Transportation Systems (OSTS). An article covering the solar cell is included in the OSTS section of this report.

The fuel cell has been the primary electrical power source for all United States manned space programs (except Mercury) because of superior flexibility, weight, and cost factors. As manned orbital activity increases with the advent of the Shuttle, extended Shuttle missions using The Power Extension Package (PEP) and space work stations such as the proposed Space Operations Center, the fuel cell and its counterpart, the electrolysis cell (for a regenerative system), will become increasingly important.

The regenerative fuel cell integrated energy system involves development of technology with many applications. With Shuttle-launched water as the resupply commodity for irrecoverable losses, it is a prime candidate for any extended duration manned or unmanned orbiting spacecraft. Shuttle-supplied water can also be used in this system for orbital manufacture of propellants for orbital transfer vehicles. It is ideally suited for space platforms in which experiments could draw power and/or hydrogen and oxygen for propellants, for feedstock for space manufacturing processes, or for life support use as required.

The expendables for a non-regenerative system required for electrical power, propulsion, life support, and thermal control for long-duration manned space missions would become a substantial portion of the lift capability of launch vehicles, thereby greatly increasing costs. In contrast the integration of the various functions of an orbital facility (electrical power, thermal control, life support, and attitude control propulsion) based upon the regenerative fuel cell concept with hydrogen, oxygen and water as the working fluids, reduces operations costs by continuous recycling of the working fluids. For the orbital

manufacture of propellants from water, the simplicity and safety of transporting and storing water will also reduce operations costs.

The 11-cell, fuel cell module (fig. 2) scheduled for use in the breadboard system to be delivered in 1982 is now undergoing a series of operational and performance tests prior to being integrated into the breadboard system.

The responsibility for this technology development is shared by JSC and the Lewis Research Center (LeRC). JSC has the acidic technology with the solid polymer electrolyte membrane and LeRC has the alkaline technology that is derived from the Shuttle capillary matrix fuel cell previously developed by JSC.

Research and technology in integrating thermal management concepts for onorbit power systems was originally initiated by the Office of Space Transportation Systems. Joint funding was subsequently provided by the Office of Space Transportation Systems and Office of Aeronautics and Space Technology. The Office of Aeronautics and Space Technology sponsored the effort in fiscal year 1981. A preliminary study indicated that the key to an onorbit thermal management concept is the creation of a centralized thermal utility system analogous to municipal public utilities, where basic "trunk" lines (buses) are provided and into which individual customers can be integrated. With such a centralized system, reduced operational and payload integration costs as well as reduced cost for all

payload users would be possible by permitting common thermal interface designs.

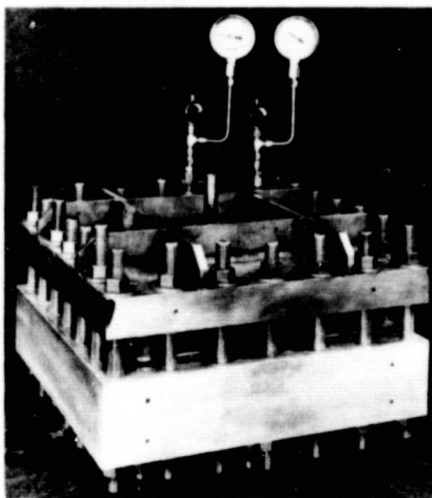
The large vacuum chamber at JSC was used as a Space Plasma Laboratory (SPL) to obtain data concerning "leakage" currents through the plasma surrounding large spacecraft surfaces at high voltage in low-Earth-orbit plasma environment. A computational model was developed to generate the trajectories of currents from sharp outer edge to collecting panel. It provides a detailed accounting for the remarkable current-focusing patterns first observed by the low light television system developed for the SPL on the surfaces of the 1- by 10-meter high voltage panel. These effects for full-scale space systems must be understood to define the design criteria needed to build and operate large high-voltage power systems for space.

An important result was obtained from the measurements of current emission during the High Voltage Plasma Interactions experiment conducted in the Space Plasma Laboratory. The hollow cathode device employed to complete the electric circuit between the current emitted by high voltage panels and the ambient plasma proved to be a more efficient motor/generator "brush" than previous concepts. This increased efficiency has revived interest in orbital motion power supply concepts using the geomagnetic field-induced voltage and a very long conductor. Further analysis of this concept for use in attitude control and station-keeping for large structures as well as for added onorbit electrical power is warranted. Space experiments to validate this concept may also be justified.

Advanced Onboard Propulsion Technology

The advanced onboard propulsion technology project will develop technology for a reusable spacecraft propulsion system using nontoxic and noncorrosive propellants. The fiscal year 1981 effort at JSC has indicated that a pump-fed liquid oxygen/hydrocarbon system with integrated Orbital Maneuvering System (OMS) and Reaction Control System (RCS) tankage provides the most efficient system for propellant packaging, ther-

Figure 2.— The 11-cell fuel cell stack.



mal control, and propellant feed. The integrated OMS and RCS concept provides the potential to increase system performance (delta velocity capability) within the current pod volume constraints or to increase the Shuttle payload by several thousand pounds.

Multifunction Synthetic Aperture Radar Technology

The Multifunction Synthetic Aperture Radar Technology project is designed to develop a low-cost automated capability to perform active (radar) sensing in multifrequencies and multipolarizations for multi-incidence angles. Such a system would enable multimission execution at a substantial cost savings. The technology areas to be addressed include antenna development, calibration, high power transmitter, broad band receiver, and control logic for multimission use.

Joint efforts with the United States Air Force and Defense Advanced Research Procurement Agency will be initiated through Memoranda of Understanding to realize significant cost and time savings in fabricating multimission synthetic aperture radars.

Large Space Systems Technology

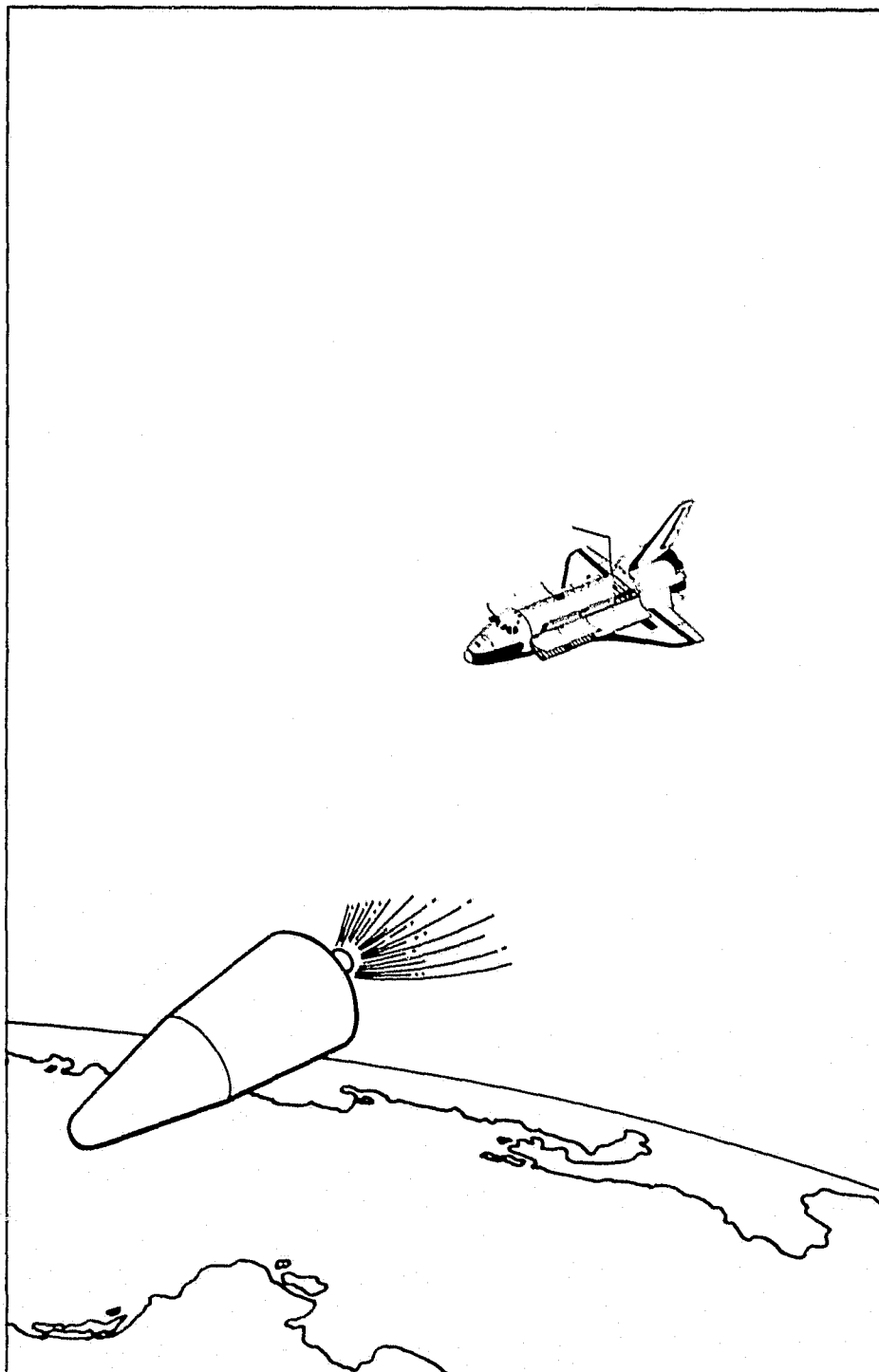
A large space system technology program has been initiated to develop techniques for space construction. To capitalize on the Shuttle's capability to provide space construction and satellite services, a Holding and Positioning Aid (HPA) is required. The HPA is used to hold a satellite or structure in a safe, stable position close to the Orbiter for construction or servicing activities, working in concert with the Remote Manipulator System and crewmen. During fiscal year 1981, two types of HPA's were conceptualized. The articulated arm-type of HPA was selected after a comparative evaluation following detailed design of the development test article.

Shuttle Launched Research Vehicle

The Shuttle Orbiter will provide a recurring capability to carry advanced, unmanned aerospace vehicles into Earth orbit. Research and technology

demonstrations in many related disciplines will be performed while these Shuttle Launched Research Vehicles maneuver, enter, and fly in the upper atmosphere before initiating a land-based recovery (see fig. 3).

Figure 3.— Shuttle-launched research vehicle.



**Office of
Aeronautics
and Space
Technology**

Significant Tasks

35 Orbiter Experiments Project Support and Integration

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: D. G. Wiseman/ED
Task Performed by: Rockwell International
Contract NAS 9-14000
Lockheed Engineering and Management
Services Company, Inc.
Contract NAS 9-15800

36 Aerodynamic Coefficient Identification Package

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: D. G. Wiseman/ED
Task Performed by: Bendix Aerospace Systems
Contract NAS 9-15588

37 Electrochemical Orbital Energy Storage Program

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: H. McBryar/EP5
Task Performed by: General Electric Company
Contract NAS 9-15831

38 Holding and Positioning Aid

Funded by: Spacecraft Systems Technology (UPN-542)
Technical Monitor: W. S. Beckham, Jr./EB
Task Performed by: Grumman Aerospace Engineering Corporation
Contract NAS 9-16276

39 Thermal Management for Onorbit Energy Systems

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: J. G. Rankin/EC2
Task Performed by: Grumman Aerospace Corporation
Contract NAS 9-15965
Vought Corporation
Contracts NAS 9-14907 and NAS 9-16321

40 High Voltage Plasma Interactions

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: J. E. McCoy/SN3
Task Performed by: Lee Parker, Inc.
Contract NAS 9-15934
Multiple additional contractors

41 Advanced Manned Vehicle Onboard Propulsion Technology

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: R. W. Polifka/EP2
Task Performed by: Aerojet Liquid Rocket Company
Contracts NAS 9-15958 and NAS 9-16282
McDonnell Douglas Corporation
Contract NAS 9-16305

42 Multifunction Synthetic Aperture Radar Technology

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: K. Krishen/ED3
Task Performed by: Jet Propulsion Laboratory
Contract NAS 7-100
Multiple additional contractors

43 Advanced Carbon-Carbon Stand-Off Panel

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: D. M. Curry/ES32
Task Performed by: Vought Corporation
Contract NAS 9-16330

44 Nonterrestrial Materials for Space Use

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: R. J. Williams/SN7
Task Performed by: Lockheed Engineering and Management
Services Company
Contract NAS 9-15800

45 Shuttle-Launched Research Vehicle

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: J. T. Visentine/ED3
Task Performed by: General Electric Company
Reentry Systems Division
Contract NAS 9-15977

46 Fire-Resistant Low-Smoke-Generating Thermally Stable End Items for Aircraft and Spacecraft

Funded by: Aeronautics Research and Technology Base (UPN-505)
Technical Monitor: D. E. Supkis/ES5
Task Performed by: Multiple Contractors

47 Toxicity Testing and Evaluation of Candidate Aircraft Materials

Funded by: Aeronautics Research and Technology Base (UPN-505)
Technical Monitor: H. Schneider/SD4
Task Performed by: Southwest Foundation for Research
and Education
Contract NAS 9-14743
Northrop Services, Inc.
Contract NAS 9-15425

48 Space Operations Center Technology Assessment

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: R. C. Kennedy/EA13
Task Performed by: Boeing Aerospace Company
Contract NAS 9-16151

Orbiter Experiments Project Support and Integration

As a pioneer (launch to landing) space vehicle, the Space Shuttle Orbiter has the potential of providing cost-effective research and technology data needed for the development of a broad spectrum of future aerospace vehicle designs or enhancements. Although the Orbiter includes instrumentation necessary to perform design verification and to monitor select operations functions, the baseline Orbiter flight test and operations program does not include plans to collect specific research and technology data relevant to the design of future vehicles.

To capitalize on the opportunity to use the Space Shuttle as a means of acquiring flight data for a wide variety of technology disciplines related to vehicle design, the Office of Aeronautics and Space Technology has established the Orbiter Experiments Program which uses the Orbiter as a flight research vehicle (fig. 1). JSC continues to support the Orbiter Experiments Program by providing (1) overall integration management and program planning, (2) technical development for specific experiments, and (3) integration of experiments into the Orbiter. The Orbiter experiments are designed (1) to augment the research and technology base for verification or enhancement of the operational efficiency of current and future aerospace vehicle design by collecting Orbiter flight data in all related technology disciplines, and (2) to correlate ground-based data with flight data by developing procedures to accurately extrapolate ground-based facility results to flight conditions.

All experiments in the Phase I repertoire of Orbiter experiments are in various stages of final development, delivery, and installation. Five Orbiter Experiments have been installed, checkout completed, and will fly on STS-2. These include the Aerodynamic Coefficient Identification Package (ACIP) reported separately in the document, Tile Gap Heating Effects (TGH), Catalytic Surface Effects (CSE), Dynamic, Acoustic, and Thermal Environment (DATE), and In-

frared Imagery of Shuttle (IRIS). See figure 1.

Two thermal protection system experiments, Tile Gap Heating Effects and Catalytic Surface Effects, are installed on the Orbiter for flight on STS-2. The results of these experiments will enable improvements in reusable element thermal protection systems (1) by optimizing the design in tile gap and edge radii thus reducing turbulent airflow and (2) by improving convective heating rates by increasing surface catalytic efficiency. Hardware for these experiments is scheduled to be flown on six flights.

The Dynamic, Acoustic, and Thermal Environment (DATE) experiment is installed in the Orbiter for STS-2. This experiment makes measurements within the payload and on the Orbital Flight Test payloads to collect information on the payload bay environment. This will be used by payload planners to accurately predict the payload environment to facilitate payload development.

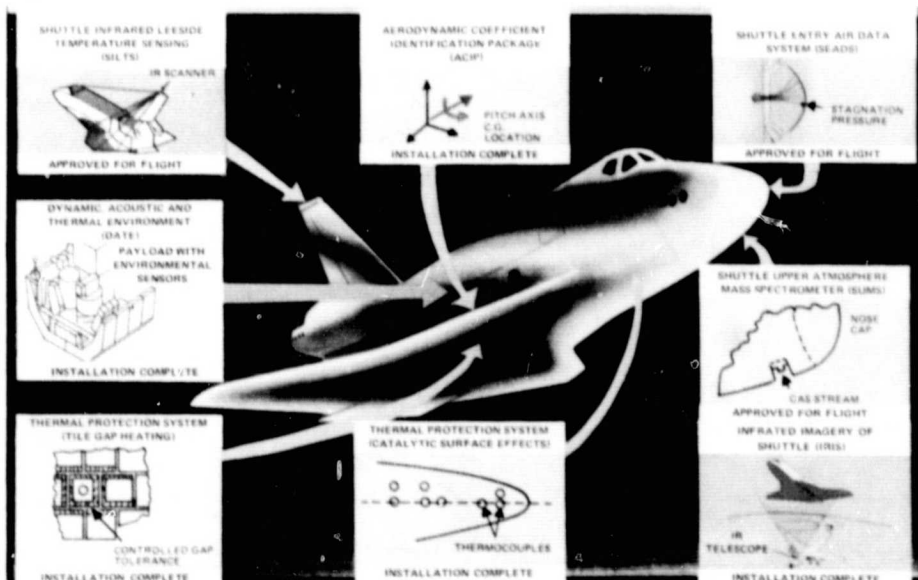
The final Orbiter experiment planned for STS-2 is the Infrared Imagery

of Shuttle (IRIS) experiment. This experiment is not an integral part of the Orbiter vehicle but involves an under-flight of the Orbiter by an instrumented C-141 aircraft during the descent phase of the flight. The objective is to obtain infrared imagery of the lower (windward) and side surfaces of the Orbiter. Thus, aerothermodynamic data is provided that cannot be duplicated at ground-based facilities.

Three additional phase I Orbiter experiments include the Shuttle Infrared Leeward Temperature Sensing (SILTS), Shuttle Upper Atmosphere Mass Spectrometer (SUMS), and the Shuttle Entry Air Data System (SEADS). These experiments have been approved for flight and will be delivered to the Kennedy Space Center for final checkout and installation.

Phase II of the Orbiter experiment program includes nineteen new experiments from the following disciplines: aerodynamics/aerothermodynamics, materials and structures, and electronics and human factors.

Figure 1.—Orbiter Experiments Program.



Aerodynamic Coefficient Identification Package

The Orbiter Program presents an unprecedented and continuing opportunity to obtain fullscale flight environment data for winged reentry vehicles (as differentiated from ballistic-type vehicles) throughout the aerodynamic regime. The quality of data produced by the Aerodynamic Coefficient Identification Package (ACIP) will provide valuable information concerning relative uncertainties associated with the extrapolation of wind tunnel tests to full-scale flight tests. The objectives of the ACIP are to collect aerodynamic data in the hypersonic, supersonic, and transonic flight regimes, regions in which there has been little opportunity to gether data; to establish an extensive aerodynamic data base for verification and correlation of ground-based test data; and to provide flight dynamics data to support other technology experiments.

The ACIP experiment will benefit the Space Shuttle Program because the precise data obtained through the ACIP will enable earlier attainment of the full operational capability of the Orbiter and contribute to the design and development of future spacecraft and aircraft.

The experiment consists of an instrument package and baseline Orbiter data that will provide flight dynamics data for the determination of aerodynamic coefficients from Orbiter flight data. The experiment utilizes Orbiter-provided power, time correlation, environmental support, and is mounted on the wing box carry-through structure on the center line of the Orbiter. See figure 1. Data are recorded on the Orbiter Experiments (OEX) supplied recorder.

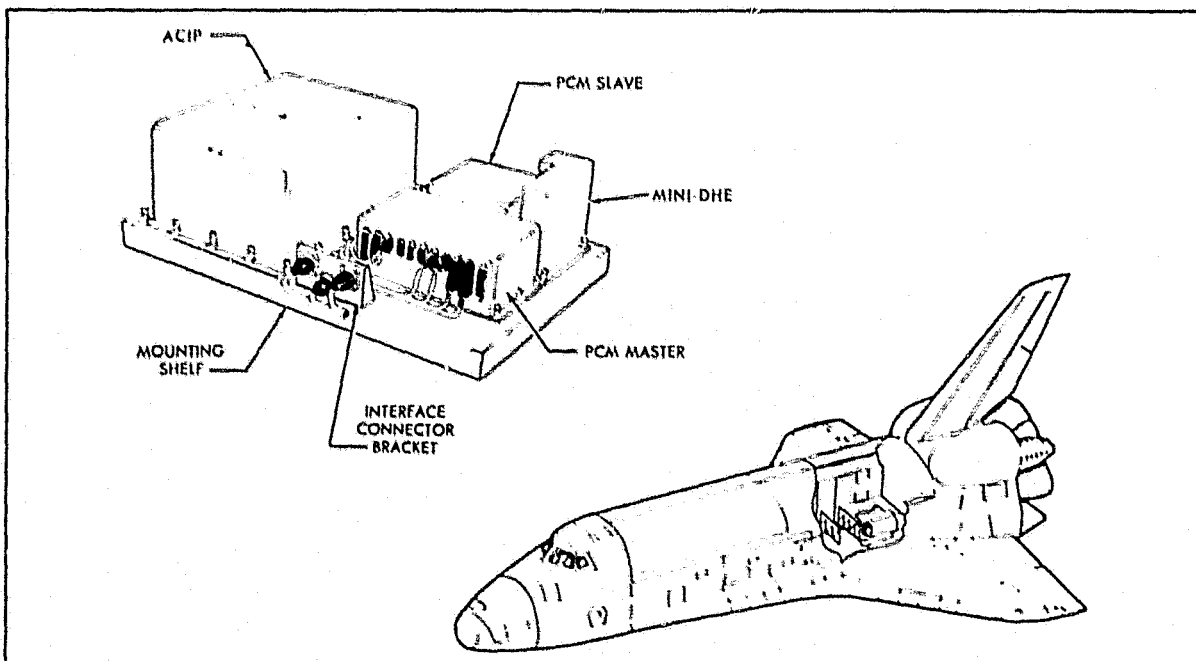
The ACIP hardware, designed, fabricated, and qualified at JSC, incorporates three triads of angular accelerometers and rate gyros. The gyro power conditioners, power control system, and housekeeping components are all self-contained in the ACIP.

The ACIP operates through the launch and ascent phases of the flight and subsequently through entry interface, descent, and landing. The internal instruments continuously sense the dynamic X, Y, and Z attitudes and performance characteristics of the Orbiter through these critical flight phases. The ACIP also receives the indications of position of the control surfaces and converts these indications into higher orders of precision before recording them with the attitude data.

The ACIP is installed on the Orbiter "Columbia" and flew on STS-1. The data gained were of the highest quality and met all expectations of the experiment designers and technologist. The acceleration and rate data depicted in detail the major events of launch, reentry, and landing. Utilization of this information with that gathered from subsequent flights will further enhance the aerodynamic data base of reentry technology.

Planned modification to the ACIP includes adding a High Resolution Accelerometer Package (HiRAP) to the existing ACIP. This supplement will provide accurate determination of aerodynamic coefficients at near orbital altitudes (up to 700 000 ft) heretofore unobtainable. Future plans also include the installation of the ACIP/HiRAP package on the next Orbiter vehicle (OV-099).

Figure 1. Location of the ACIP



Electrochemical Orbital Energy Storage Program

The separation of water into hydrogen and oxygen by the passage of an electric current through an aqueous medium is essentially the reverse reaction of a fuel cell. The fuel cell has been the primary electrical power source for all U.S. manned space programs (except Mercury) because of superior flexibility, weight, and cost factors and continues to be the most viable candidate for 1 to 2 week missions to be conducted using the Shuttle. As manned orbital activity increases, such as with extended Shuttle missions and work stations (Space Operations Center), the fuel cell and its counterpart, electrolysis cells (for a regenerative system), will become increasingly important.

In a regenerative fuel cell system configuration, the role of fuel cells — in addition to its primary function of providing electrical power to the vehicle and to the experiments on the dark side of the orbit — is to provide potable water for the crew and for certain thermal control requirements. The role of electrolysis cells is to recycle fuel-cell-produced water, metabolic water, and makeup water by using solar-array-produced power on the light side of the orbit. Thus, energy storage is provided for indefinite orbital stay times.

Recycling of water in a regenerative system is an increasingly important consideration in space missions. In addition to regenerating the hydrogen and oxygen required for the fuel cell, anticipated propulsion system propellants are almost exclusively hydrogen and oxygen, and space manufacturing may use large quantities of hydrogen and oxygen for various processes. Thus, metabolic waste water that may be undesirable for recycling for metabolic use may be diverted to propulsion and/or to manufacturing requirements yielding multiple uses from a single commodity.

The expendables for a non-regenerative system required for electrical power, propulsion, and life support and thermal control for long-duration manned space missions would become a substantial portion of the lift capability of launch vehicles

thereby greatly increasing costs. In contrast, the integration of the various functions of an orbital facility (electrical power, thermal control, life support, and attitude control propulsion) based upon the regenerative fuel cell concept with hydrogen, oxygen, and water as the working fluids should minimize operations costs by continuous recycling of the working fluids. For the orbital manufacture of propellants from water, the simplicity and safety of transporting and storing water will also economize operations costs. A field test of an engineering model test article is planned for 1986. The technology should be available for orbital use in the late 1980's or early 1990's.

The responsibility for this technology development is shared by JSC and the Lewis Research Center (LeRC). JSC has the acidic technology with the solid polymer electrolyte membrane and LeRC has the alkaline technology that is derived from the Shuttle capillary matrix fuel cell previously developed by JSC.

In May 1979, a potential multiyear technology program was initiated by NASA to bring to maturity the solid polymer electrolyte electrochemical cell technology as a candidate for low-earth-orbit energy storage applications. Objectives of this program are to (1) advance the technology of dedicated electrolysis/fuel cells and reversible cells for basic improvements of efficiency and life, (2) deliver development model modules for interim breadboard testing of cyclic electrolysis and fuel cell operation, and (3) deliver engineering model modules, based upon breadboard evaluation and technology development, for a technology readiness demonstration test in 1986.

A state-of-the-art technology assessment and system optimization study was completed, including identification of goals for advancements in fuel cell and electrolysis cell technologies. Laboratory cells have been tested under typical operating conditions to demonstrate the feasibility of designing the system using either a single electrochemical module operating reversibly to provide both fuel cell and electrolysis functions, or to use separate (dedicated) fuel cell and electrolysis modules, each optimized

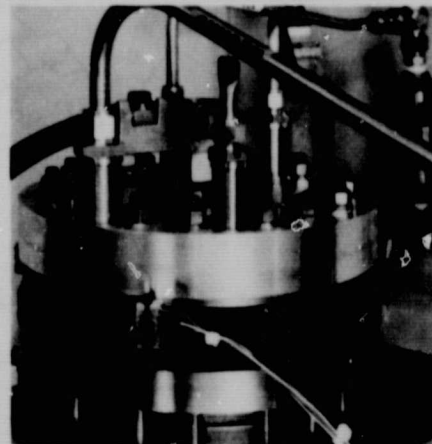
for its own function. However, the system study showed that the dedicated modules resulted in a lower overall system weight, higher efficiency, and greater operational flexibility. Therefore, subsequent efforts have been directed toward that type of system.

A 6-cell stack of full size (32-square-inch active area) electrolysis cells (see fig. 1) has been tested in a microprocessor controlled subsystem installation for approximately 1500 hours (1630 simulated orbital cycles) during the past year. A 3-cell (158-square-inch active area cells) fuel cell subsystem will soon be added to complete an integrated test system used to evaluate overall system operation and performance and becomes a test bed for evaluating components and controls for the breadboard system scheduled for delivery to NASA in 1982.

The 11-cell fuel cell module scheduled for use in the breadboard system is being tested in a separate facility. A series of operational and performance tests will be performed before it is integrated into the breadboard system.

In a parallel effort, advanced technology development is underway to achieve the weight and performance improvement goals. Laboratory cells incorporating a unique oxygen electrode support configuration are performing near the desired level.

Figure 1.— Six-cell electrolysis stack.



Holding and Positioning Aid (HPA)

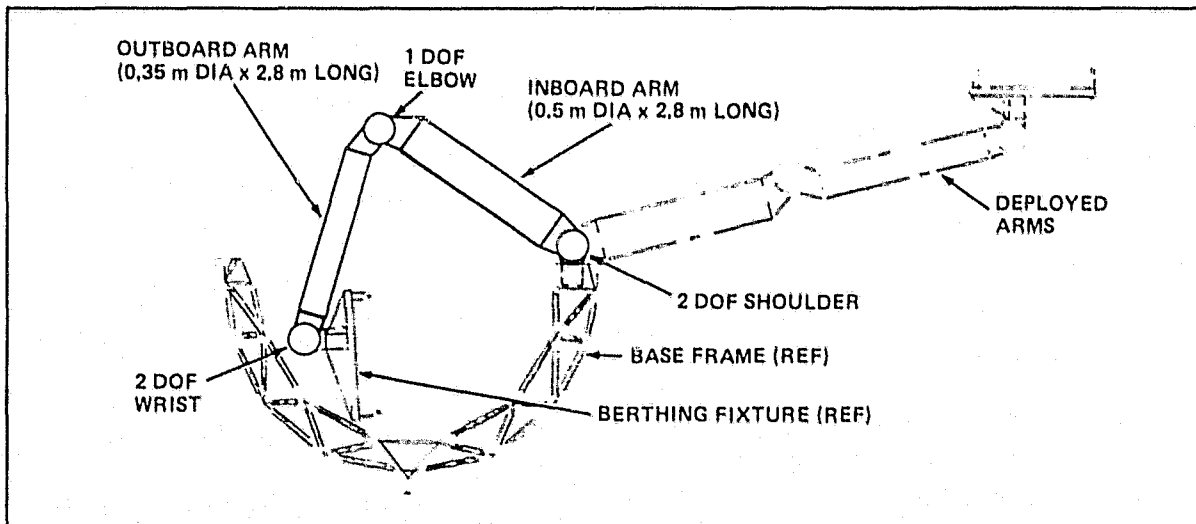
In addition to its basic role as a space transportation system, the Space Shuttle will provide the capability for space construction and satellite services that were not previously available. One basic requirement to use this capability is a system called the Holding and Positioning Aid (HPA) that can be used to hold a satellite or structure in a safe and stable position near the Orbiter for construction or servicing. The HPA will be used in conjunction with the Remote Manipulator System (RMS) and EVA crewmen and needs to be capable of indexing the construction or servicing needs within the reach envelope of the RMS. The system should provide sufficient stiffness and strength to hold large masses near the Orbiter under various induced load conditions.

To define the design envelope, a series of potential missions was postulated. These missions included large space structures fabrication, berthing of Orbiter to satellites of varying masses, and servicing of existing and proposed satellites. The mission requirements established the design requirements for the system. Conceptual designs for flight systems were developed and analyzed. The selected flight system concept was used as the basis for detailed design of a Development Test Article (DTA) (fig. 1). The DTA will be fabricated in the next year and be installed in the Manipulator Development Facility (MDF) at JSC for evaluation and testing.

During fiscal year 1981, the requirements analysis was completed. Two types of the HPA were conceptualized that met all mission requirements: a tilt table and an articulated arm. Both use a lightweight cradle mounted in the payload bay using a single keel-fitting and four longeron attach fittings. In the tilt-table version, a cross beam is installed with a choice of several docking interfaces mounted on the cross beam. This system was estimated to weigh 1080 pounds. In the articulated arm version, 5-degrees of freedom are provided: 2 at the shoulder, 2 at the wrist, and one at the elbow. Inner and outer arms are of equal length (110 inches). The articulated arm is mounted on the same cradle used for the tilt table and is estimated to weigh 1760 pounds in the flight version.

The articulated arm-type of HPA was selected after a detailed comparative evaluation, and the detailed design of the development test article (DTA) was completed. Fabrication of the DTA is scheduled for fiscal year 1982 and development tests will be initiated in fiscal year 1983.

Figure 1.—HPA development test article.



Thermal Management for Onorbit Energy Systems

For the next generation of space missions, much longer lifetimes and much higher power levels will be required than in any previous missions. Efficient thermal management is mandatory because generation, transfer, and storage of the electrical energy needed for these future space missions will result in the dissipation of huge quantities of waste heat. A low cost, reliable orbital thermal management system does not currently exist and must be provided for major future orbital operation systems. Such a system would need to overcome the previously discussed limitations of current system designs. Therefore, ways to increase energy capacity, reject waste heat, extend the operating capability of Shuttle, and provide power for a broad range of space applications will require an entirely new effort in thermal management.

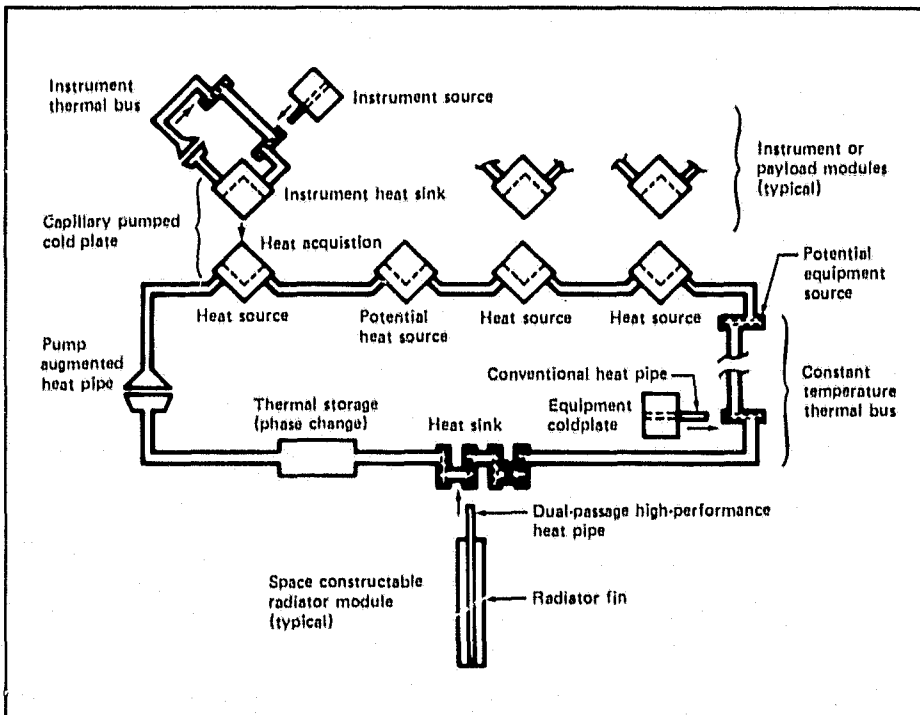
The key to the thermal management concept lies in the creation of a thermal "utility" system, analogous to municipal public utilities, where basic "trunk" lines are provided and into which individual customers can be integrated. The system must be designed so changes in location or load of individual customers have minimal effect on the utility's capability to serve loads of the remaining customers. Such a centralized system would allow reduced operational and payload integration costs, as well as reduced cost for all payload users by allowing common instrument thermal designs. Reduction in thermal management system costs can be achieved through system modularity; subsystems integration; stepwise growth capability to very large satellites; volume and weight reduction; extended life by maintenance/replacement, materials compatibility, and insensitivity to environmental conditions; and expansion of

the thermal management technology base to provide simpler, more reliable systems.

A schematic representation of a candidate thermal management system concept is shown in figure 1. The system consists of a central two-phase fluid transport loop that is thermally connected to a variety of heat sources and sinks. As shown, the sources can be individual pieces of equipment or smaller versions of the central system, each transporting heat to its own variety of interfacing hardware. In keeping with the "utility" concept, not all of the potential interface locations would necessarily be filled during a particular mission phase. The location of the heat sources in relation to each other in the loop would not be critical (as it is in current pumped-fluid systems) since all the heat transfer is taking place at a fairly constant temperature via evaporation or condensation of the working fluid.

A preliminary study to screen candidate concepts for the centralized thermal bus began in fiscal year 1981. The results of this study, due to be completed in December 1981, will be utilized in establishing the specifications for development of a thermal bus system concept from the initial design phase through hardware fabrication to thermal vacuum testing. Plans also call for the design, fabrication, and checkout of a prototype constructable radiator test article, followed by thermal vacuum testing at JSC in mid-1983. These subsystem-level efforts would be followed by a system level integration and test phase in which the thermodynamic performance and operating procedures for the complete thermal management system would be investigated.

Figure 1.— Advanced thermal management system concept.



High Voltage Plasma Interactions

Interactions between the space plasma in low Earth orbits (LEO) and large spacecraft surfaces at high voltage are capable of carrying significant "leakage" currents through the surrounding plasma. The complex physical processes operating to limit, or multiply, these effects for full-scale space systems must be explored and understood to develop large power systems for space.

To address this problem, the program at JSC has employed large-scale experiments in the unique 20- by 30-meter Space Plasma Laboratory (SPL) operated in Chamber A, together with development of computer programs, to allow numerical simulation of the space charge sheaths around large high-voltage arrays.

The SPL test program provides a direct experimental link between smaller scale experiments, analytical models, and much larger space flight systems. This is important to reduce the large errors often encountered in scaling hypothetical plasma behavior beyond an existing data base. The large size of the facility at JSC allows two critical experimental parameters to be obtained — low plasma temperature and adequate plasma volume for free-space development of the high-voltage plasma sheaths.

Several significant results were obtained from the large chamber experiments. The total plasma leakage currents for a 1- by 10-meter high-voltage panel were much lower than earlier estimates. The space-charge limited sheaths around the panel, observed directly for the first time, show rather sharply defined outer boundaries confining their electric fields and limiting current collection. This led to the adoption of a basically different model (Sharp Sheath Edge Model) for plasma current-leakage calculations than that generally used by NASA to date.

This model accounts for the observed ineffectiveness of surface insulation in reducing plasma leakage currents. Reducing the exposed conductor area on a given array was shown by several experiments to be ineffective, and sometimes counter-

productive in reducing current drain to the plasma. Similar results were obtained by using 1- by 10-meter panels and actual flight prototype Power Extension Package (PEP) solar arrays. The PEP solar array was tested under full space-solar illumination while generating 40 to 80 watts power output. In all cases, insulation of more than 90 percent of the originally exposed conductor surface area resulted in less than 40 percent reduction in plasma leakage current. Above 200 volts, plasma current drain was actually multiplied by the added insulation.

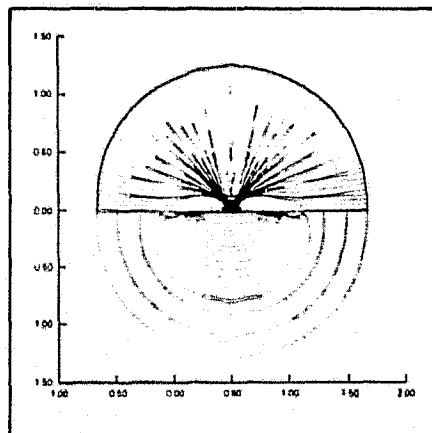
The computer effort has been greatly advanced by adoption of the sharp sheath edge model, which allows a great reduction in computer time required for a rigorous solution. The new software (CLPH) uses relaxation of an approximate solution to a selfconsistent equilibrium. Two breakthroughs have resulted from use of the CLPH. The trajectories of currents from sharp outer edge to collect-

ing panel can be mapped to provide a detailed accounting of the distinct current-focusing patterns on the surface of the high-voltage panel (first observed by the low light television system developed for the Space Plasma Laboratory). Response by the sheath to attempts to measure it by external probes has also been calculated to involve very significant self-disturbance (see fig 1).

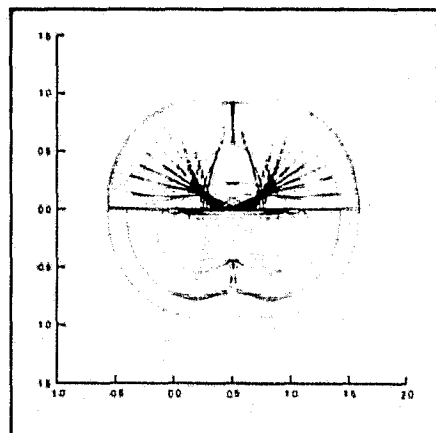
The results indicate the importance of future application of both experimental and computational techniques in a coordinated iterative manner, to verify results or reveal errors in each. The computation routines can be used in post-experiment analysis to account for anomalous results of variations in actual plasma conditions or experiment configuration from those expected. In effect, repeated computer "experiments" can be conducted, varying only one parameter at a time, until either a match to the actual result is obtained or all known explanations for the unexpected result are ruled out.

Figure 1.— Computer program plot of plasma sheath solution.

(a) Plot showing cross-section view in a plane perpendicular to 1- by 10-meter (simulated solar array) panel at -3000 V surface potential. The 1-meter panel width is oriented left to right at center of figure with voltage contours plotted in space below the panel and corresponding current trajectories from plasma to panel plotted in space above panel. Plots extend out from panel until reaching location of sharp sheath edge (at assumed potential of 1 volt).



(b) Identical system as (a) with addition of 1/2-inch Langmuir probe at +100 V inserted 0.5 meter from the 1- by 10-meter panel surface at -3000 V. Note the radical change in internal sheath potential contours and current paths and resulting distribution on surface of panel.



Advanced Manned Vehicle Onboard Propulsion Technology

The present man-rated spacecraft propulsion systems use a toxic, corrosive, and expensive hypergolic propellant combination of nitrogen tetroxide/monomethyl hydrazine. For future highly reusable manned spacecraft propulsion systems, such as a second-generation Space Shuttle auxiliary propulsion system, the hypergolic propellant combination will probably be phased out in favor of a noncorrosive, nontoxic, and less costly propellant combination. Preliminary studies indicate that the liquid oxygen/hydrocarbon propellant family provides the most attractive alternative and that an increase in system complexity will be unavoidable with these cryogenic propellants.

The present spacecraft auxiliary propulsion technology data base is too limited to allow selection of an optimum system and propellant combination. The objectives of this effort are to identify viable auxiliary propulsion system designs and propellant combinations to replace hypergolic propellant systems and to develop the technology base that will allow an orderly and cost-effective selection and subsequent development of a second-generation Shuttle auxiliary propulsion system. Results will also have applicability to other advanced spacecraft systems with similar duty cycle requirements.

Analytical and subscale experimental efforts are being conducted over a wide range of operating conditions to provide basic propellant combustion and thrust chamber cooling characteristics for promising propellant combinations. Preliminary system design and trade studies are being conducted to (1) determine the inherent design, performance, and operational characteristics of promising propellant combinations and system concepts, (2) provide a common basis to compare the weight, mission performance, cost, and operational characteristics of promising propellant combinations and system concepts, and (3) identify

critical areas where full-scale component level technology efforts would be most beneficial.

High-speed color photography of single-element combustion has been used to qualitatively characterize the basic combustion trends of different propellant combinations and injector element designs over a wide range of operating conditions.

Resistance-heated tubes that simulate actual engine operating conditions have been used to characterize the thrust chamber regenerative cooling capability of propane.

Subscale injectors of approximately 1000 pounds force are being tested to characterize the combustion performance, stability, and gas side heat transfer characteristics of promising propellant combinations.

An overall systems study is being conducted to compare candidate liquid oxygen/hydrocarbon auxiliary propulsion system concepts.

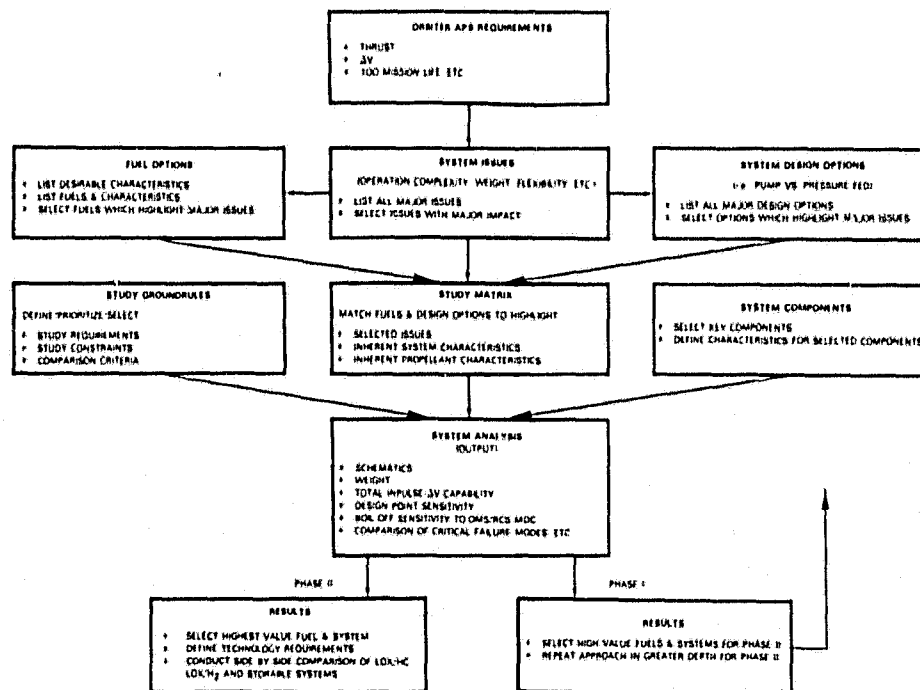
Testing of unlike spray and unlike coherent jet impinging element injectors with liquid oxygen and propane at a nominal pressure of 300 pounds per square inch has substantiated trends

identified in the previous single-element combustion photography effort. That is, the magnitude of propellant spray pattern striation (reactive stream separation) associated with unlike spray impinging element injectors results in significant performance losses. The coherent jet impinging element injector did not suffer significant performance losses for the conditions tested. Future efforts will include testing of other promising fuels as well as measurement of gas side heat flux.

The overall system design and concept selection study approach is outlined in figure 1. The candidate propellant combinations being evaluated are oxygen/propane, oxygen/methane, oxygen/ammonia, and oxygen/ethyl alcohol. The design options to be considered in Phase I will include: pump versus pressure feed; helium versus boost pump; cryogenic versus ambient propellant feed; foam/fibrous versus multi-layer insulation; and degree of orbit maneuvering and attitude control system integration.

Future efforts will include completion of the systems design study and the initiation of an experimental ignition and pulsing thruster program.

Figure 1.— Study approach



Multifunction Synthetic Aperture Radar Technology

The present state-of-the-art capabilities of spaceborne imaging radars include single-frequency, single-polarization combination, and swaths up to 100 kilometers. Technology advancement is needed to enable the development of multimission, multifunction, wide-swath synthetic aperture radars (SAR's) with selectable functional parameters. The multimission, multifunction SAR's will satisfy multimission objectives at substantial cost savings; e.g., Earth resources and ocean surveys in the same mission.

The planned and potential NASA synthetic aperture radar (SAR) missions for the 1980's include: Shuttle advanced microwave experiment (SAMEX), free-flying imaging radar experiment (FIREX), aircraft imaging radar experiment (AIREX), Venus orbiting imaging radar (VOIR), and the U.S./Canadian SAR mission (fig. 1). The NASA Active Microwave Remote Sensing Research Program Plan identifies SAR functional parameter requirements for remote sensing in the geology, agriculture and forestry, water resources, oceans and polar ice application areas that include the following:

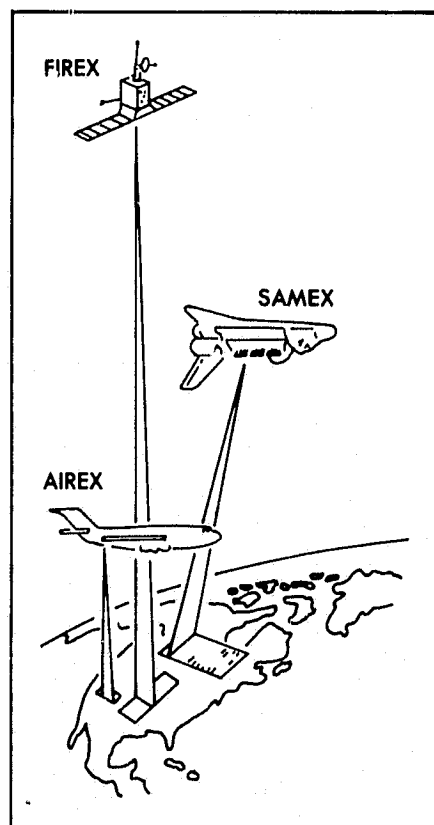
Wavelengths of SAR operation:	L- to K_U - bands
Polarization combinations:	HH, VV, and cross
Resolution:	10 m to 300 m
Swaths:	100 Km to 500 Km
Incidence angles:	15° to 60°
Calibration:	
Amplitude:	2 dB accuracy, 1 dB precision (1 σ variation)
Spatial:	10 m to 300 m accuracy (1 σ variation)

During 1980 NASA developed a conceptual SAR design that could operate at selectable frequencies (L- to X-band), selectable polarization combination, and selectable angle of incidence. This study identified key technology areas needing further development to enable the fabrication of

multimission and multifunction SAR's for space applications. During fiscal year 1981, a program was initiated to address the designated antenna, high-power SAR transmitter, SAR calibration, and wide-swath SAR technology development. The program element objectives are as follows.

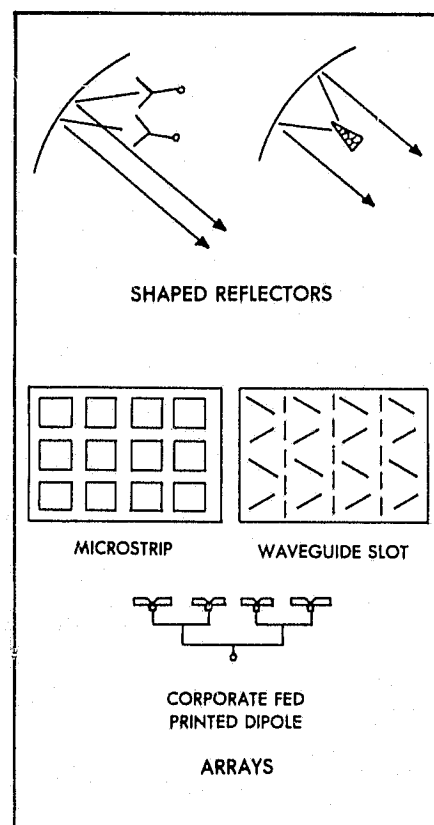
1. Develop design approaches and demonstrate antenna system technology for multifrequency, multipolarization, wide-swath SAR systems (fig. 2).
2. Identify approaches, develop the necessary subsystems, and demonstrate calibration for Earth observation SAR systems.
3. Develop a high-power, reliable, and efficient microwave transmitter to meet the needs of future spacecraft SAR's.
4. Develop multibeam wide-swath SAR concept and demonstrate the design using ground-based subsystems.
5. Develop design approaches for potential Earth observation SAR's that incorporate designs/techniques identified through this technology development program.

Figure 1.— Some potential SAR missions.



Fiscal year 1981 accomplishments on the multifunction SAR technology program include (1) Specifications and fabrication plan for advanced multimission antenna designs for laboratory demonstration, (2) Plan for systematic approach to SAR calibration technology development, (3) SAR sensor error analysis procedure for calibration, (4) Design approach for high power combining architecture in vacuum, and (5) Computer-verified multibeam squint-mode SAR design concept. Based on the fiscal year 1981 effort, specific subsystems will be fabricated to develop and demonstrate the technology. This effort is planned to continue to FY1986. Joint efforts with U.S. Air Force and Defense Advanced Research Procurement Agency will be initiated through Memoranda of Understanding to realize significant cost and time savings for both the Department of Defense and NASA.

Figure 2.— Candidate SAR antenna technology areas.



Advanced Carbon-Carbon Stand-Off Panel

The Shuttle Orbiter thermal protection system (TPS) around doors, hatches, interface regions, and various penetrations consists of densified reusable surface insulation (RSI) and gap fillers. This current baseline TPS is subject to step/gap problems and damage induced by manufacturing operations, impacts from debris, et cetera. Further, this installation is difficult to inspect for installation quality. It is anticipated that selective RSI areas on the Orbiter could be retrofitted with advanced carbon stand-off panel at no weight increase. The panel would provide a more durable and impact resistant surface, reduce step and gap problems, provide greater margin in high load regions, a more reliable attachment system and good maintainability with minimum turnaround.

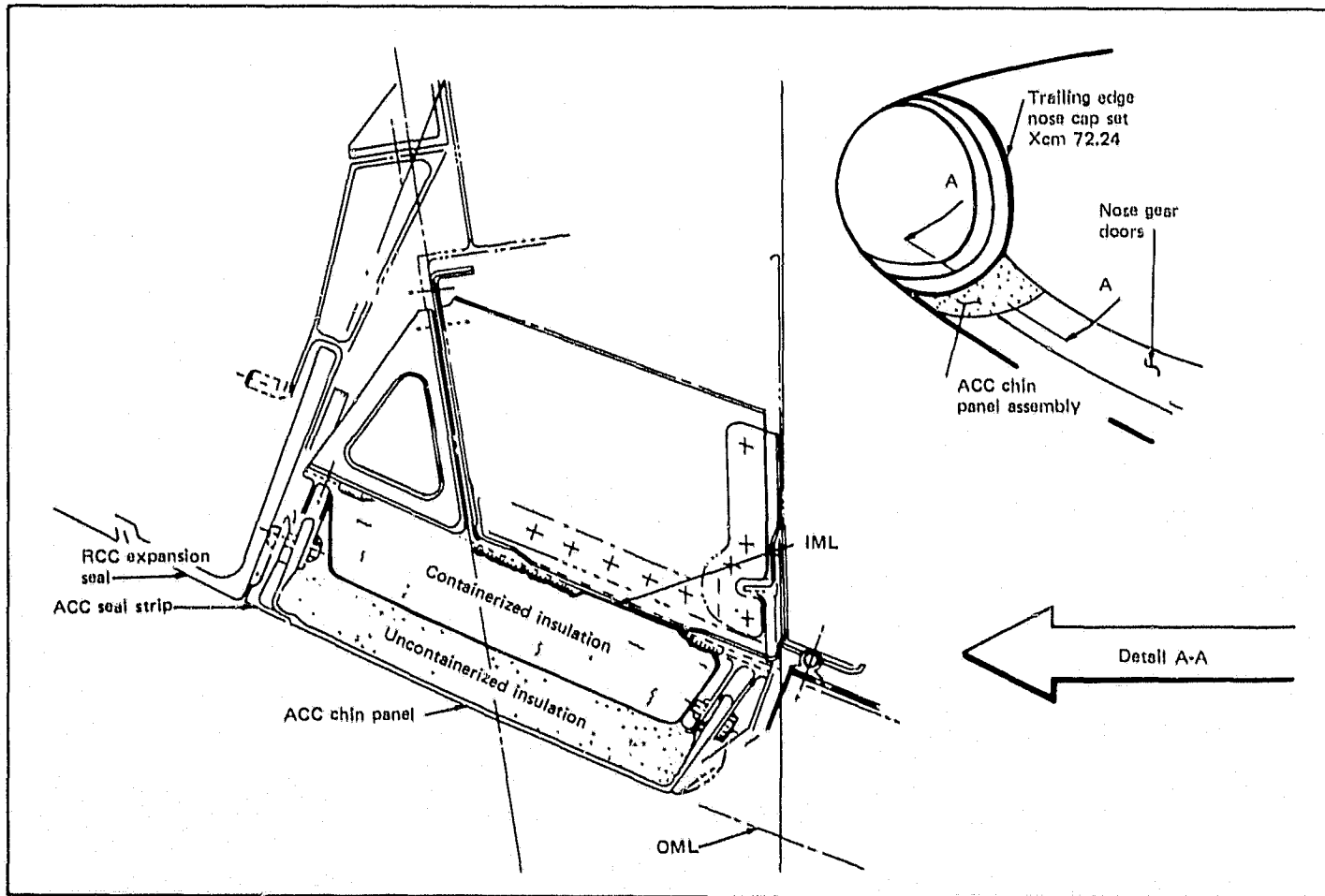
The contractor will design, perform analytical studies, and fabricate a carbon stand-off panel using the advanced carbon-carbon material. This material will replace the RSI tiles between the nose cap and nose landing gear door and extending transversally to approximately the nose gear doors outboard trim line. The prototype panel will be delivered to NASA/JSC for full-scale testing by using the nose cap test article (T-5) as the test bed.

During fiscal year 1981, panel conceptual design studies were completed and selection of a concept for installation on the nose cap test article was made that provides for adjustment along the leading edge and sides to maximize retrofitability on the Orbiter. Parametric thermal analyses were conducted to optimize the basic insulation mix and to provide guidance on supporting fitting design. Three-dimensional thermal model construction is underway.

Finite element static analysis has been conducted providing an indication of acceptability of the thin skinned concept. Methods for proving panel stability for crush pressure are being evaluated.

A finite element dynamic analysis is in progress. Mode shapes and response frequencies have been computed. Preliminary examination of panel stresses indicates that the combination of static and dynamic stresses will be manageable with the selected concept.

Figure 1.— ACC chin panel - candidate concept.



Nonterrestrial Materials for Space Use

Future space activities may involve the construction of very large structures in space. Because significantly less energy is required to launch materials from the Moon than from the Earth, these large-scale space activities may benefit from the development of manufacturing industries in space that obtain their raw materials from the rocks and minerals of the Moon.

This year's activities have been dominated by a change in focus of our activities away from the chemical processing studies, which have been the central thrust of this effort for the last four years, toward the separation of mineral concentrates from lunar materials.

Mineral separation will be important because the raw material available, the lunar regolith, is a complex mixture of rock, mineral, and glass fragments. If separations can be performed, it should be possible to simplify both the complexity and size of chemical processing. The lunar regolith materials present challenges to technology because they are physically complex and because they are very fine-grained (average grain size less than $60\text{ }\mu\text{m}$). In addition, there is a strong motivation to use fluidless separation techniques because of the vacuum environment of space. Consequently, JSC efforts were directed toward four major goals:

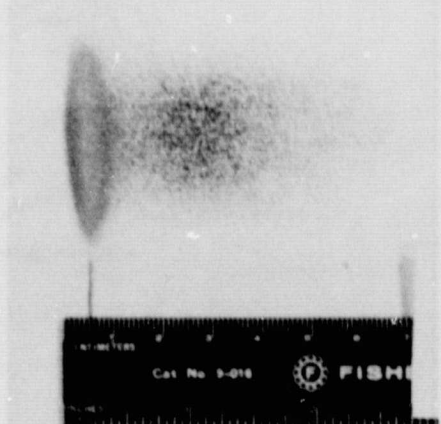
- (1) The establishment of a laboratory with mineral separation and handling facilities capable of attaining the cleanliness standards required for actual lunar sample use.
- (2) The design and construction of electrostatic and electromagnetic separation systems, with capabilities for use in dry nitrogen and in vacuum.
- (3) The production of materials from which mineralogic and grain size simulants to lunar samples would be made.
- (4) Testing of separations using prototype equipment.

During the year, a laboratory area was established and refitted with standard equipment to meet test requirements. The test system was designed and fabricated. Several rocks and minerals (olivine, pyroxene, ilmenite, and anorthositic gabbro) have been crushed, ground, and sieved into the seven standard size fractions used to characterize lunar soils. In addition, a synthetic glass of the composition of lunar basalt has been treated to introduce fine-grained metallic iron. By combining these materials in various proportions, they can be used to construct a variety of simulants to lunar regolith materials. The mineralogic composition, the amount of glass, and the grain size of the simulant can be controlled.

The last phase of this year's work involved tests using a prototype electrostatic separation system (vibrating feeder with a flatplate electrode). A fine-grained (45 to $90\text{ }\mu\text{m}$) mixture of olivine and ilmenite (5:1 ratio) was used in the tests. The best separations (fig. 1) were obtained with the electrode vertical, a 2 cm separation between feeder and electrode, and the electrode biased positive at 5000 volts with respect to the feeder. Under these conditions, both minerals are attracted to the electrode; on the electrode the ilmenite, which is an electrical conductor, acquires a positive charge and is repelled from the plate; the olivine adheres to the electrode and drops vertically. As judged by the color of the resultant material separates, the separations are quite clean and the ilmenite appears to be sorted with respect to grain size with the finest grained materials repelled the farthest from the plate.

These results are being integrated into the test plans and tests with a new system will be conducted this fall. Various simulant mixtures will be tested, beginning with simple simulants and progressing to more lunar-like mixtures.

Figure 1.— Laboratory result of electromagnetic separation of lunar material. Olivine (light color) is concentrated directly beneath the vertical flat plate electrode. The ilmenite (black) farthest from the olivine is finer-grained than that immediately adjacent to the olivine.



Shuttle-Launched Research Vehicle

The initiation of operational Space Shuttle flights in the 1980's will provide the aerospace community with many unique opportunities to demonstrate and evaluate advanced space vehicle design concepts. The narrow entry corridor of the Orbiter and the inherent limitations of ground-based laboratories to simulate entry and aerothermal flight environments dictate a need for a separate category of entry research vehicles. The frequency of flights into space by the Orbiter will provide a recurring capability to carry advanced, unmanned aerospace vehicles into Earth orbit and perform research and technology demonstrations in many related disciplines while these vehicles maneuver, enter, and fly in the upper atmosphere before initiating a land-based recovery.

The Shuttle-Launched Research Vehicle (SLRV) program will enable the NASA flight research centers to expand their knowledge in entry and hypersonic technologies for future developments in the Earth and planetary space programs, and will provide principal investigators with a dynamic flight research facility that will lead to new generations of operational space flight vehicles.

The SLPV would be used to demonstrate new technology concepts in hypersonic flight environments that lie outside the operational envelope of the Shuttle Orbiter. These concepts include aeromaneuvering systems for reusable orbital transfer vehicles and planetary orbiters, advanced thermal protection system materials for planetary entry probes and future generations of Earth-to-orbit transport vehicles, and control-configured designs for heavy-lift launch vehicles.

The SLRV program uses the Orbiter's payload capability for advanced technology research and development and extends the aerodynamic and aerothermodynamic research that will be conducted from the Space Shuttle during the Orbiter Experiments Program.

The SLRV concept provides a common electronics "core" system to which various aeroshell or fuselage configurations can be attached. This "core" will provide all normal avionics, control, data, communications, power,

and maneuvering capability for unmanned subscale reentry vehicles. Experiments selected for these vehicles would be designed to provide research data to support the Office of Aeronautics and Space Technology research programs in advanced space transportation systems and planetary entry technology. Aeroshell and fuselage configurations would satisfy specific experimental objectives and would fall into three categories: ballistic, medium lift-to-drag (L/D) ratio lifting bodies, and high L/D ratio lifting bodies.

The SLRV development program is designed with primary emphasis directed toward cost-effectiveness. This program employs a phased programmatic approach whereby development of the flight vehicles will be initiated on a modest scale. Major decisions for subsequent growth will follow technical advancements made during earlier phases of the flight research program. These decisions will also consider the research data obtained from the Orbiter Experiments Program.

Significant program activities accomplished this year at JSC include completion of a SLRV applications and cost-benefits study and initiation of vehicle design concept studies. The purpose of the applications study was to identify "high-yield" technology

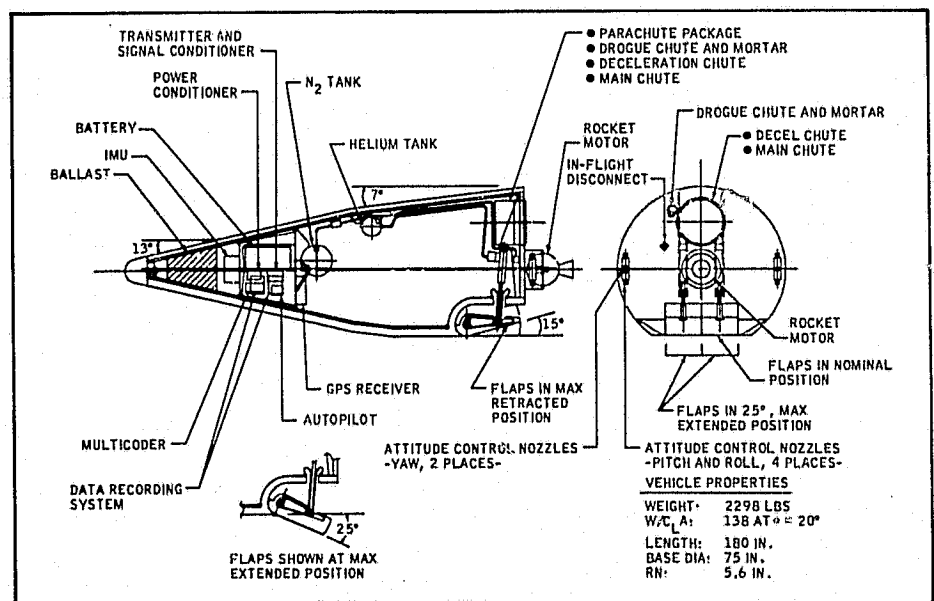
demonstrations that would significantly benefit the development of future generations of space transportation vehicles and planetary spacecraft and to propose various configurations of SLRV vehicles to accommodate these demonstrations. The design concept studies will consider the most promising SLRV designs in more detail and will identify subsystem performance requirements.

The applications study has resulted in the identification of 28 research and technology experiments and two candidate vehicle configurations for the SLRV. These vehicle configurations include ballistic and variable-trim biconic.

The variable-trim vehicle (fig. 1) provides the greatest versatility. This vehicle will use split windward flaps to fly at various angles of attack during entry. It will flight test both windward and leeward advanced thermal protection system design concepts and advanced flight control system within reentry environments and flight corridors that are unattainable using the Shuttle Orbiter.

Discussions were held between NASA and the Air Force to determine if a joint synergism exists. The SLRV could be used to obtain initial performance data and develop a data base for Air Force hypersonic flight test experiments.

Figure 1.— Maneuverable Shuttle-launched research vehicle (split windward flap configuration).



Fire-Resistant Low-Smoke-Generating Thermally Stable End Items for Aircraft and Spacecraft.

The general objectives of the program, called the Firemen Program, are to develop and apply fire-resistant materials technology to the survivable crash and ramp fires in commercial aircraft and to conduct systems testing of new and modified fire-resistant materials in configurations such as aircraft, wall and floor panels, seats, fuselage sections, and the overall cabin area. The detailed objectives of the program are the following:

1. To demonstrate that the introduction of fire-barrier materials in the exterior wall will prevent an external "design" fire from entering closed habitable areas for the minimum 5-minute period needed for passenger evacuation.

2. To demonstrate that a closed cabin will not reach a temperature of 400° F (considered a lethal temperature for humans) nor generate smoke or toxic gases at temperatures up to 400° F during a specified "design" fire.

3. To demonstrate that a "design" fire in the area of a cabin opening will not propagate throughout the cabin area during the minimum 5-minute period.

Under these general objectives, three specific tasks were undertaken in a phased approach.

1. Polyimide Developments: (a) Resilient Foam - Continued development of nonflammable resilient foam for seat cushion use. (b) Semi-Rigid and Rigid Foam - Continued development of these nonflammable foams for general applications. (c) Foam Production - Completed pilot plant demonstration of polyimide foam production.

2. Aircraft sidewall burnthrough evaluation: (a) Conducted burnthrough tests on configurations representative of Boeing 727, Douglas DC-10, and Lockheed L-1011 sidewalls. (b) Completed manufacture of improved panels for future testing.

3. Wall and Ceiling Panels - Currently developing Fluorel (fluorocarbon elastomer) paneling material for use in wall and ceiling panel.

NASA development of polyimide foams was initiated several years ago based on technology produced for turbine engine insulation. The developments have produced a resilient seat cushion foam that has excellent fire resistant characteristics. The polyimide foams have been produced at pilot plant capacities and have been tested for flammability characteristics in two NASA study contracts, as well as in a full-scale Federal Aviation Administration (FAA) test conducted at

FAA Technical Center. Figure 1 is a post-test photograph showing minimal damage to the polyimide foam in the FAA full-scale test. All results indicate that the foam is basically nonflame propagating, in direct contrast to the current polyurethane foam which acts as a fuel in full-scale fires.

The polyimide foam has also been tested by major seat manufacturers for seating characteristics. Based on the seating evaluation results and flammability characteristics, one company is manufacturing seats for flight evaluation and marketing demonstrations. The foam has a significant advantage over current seating cushions in a weight savings of 40 percent. Commercial quantities up to 1 million pounds per year will be available starting in December 1981.

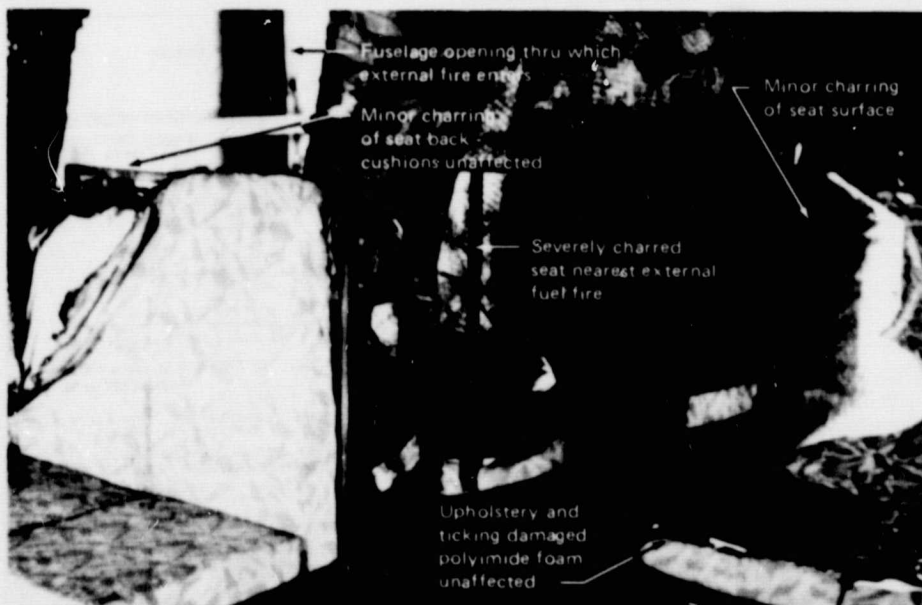
A version of the polyimide semi-rigid-foam including ceramic fibers shows promise as an aircraft sidewall insulation. This material can withstand a higher heating environment than the current glass insulation and, therefore, may be a good fire barrier sidewall candidate. Panel tests of this material are planned.

The aircraft panel burnthrough test program has produced burnthrough characteristics for three baseline sidewall configurations. These baseline configurations are for the Boeing 727, Douglas DC-10 and Lockheed L-1011. Each contained insulation, insulation bagging, interior wall panels, metal frames, and exterior aluminum skin. All three of these configurations had burnthrough times in a JET A-1 fuel fire of 90 seconds. Improved configurations are being developed for testing.

Rigid polyimide foam also was incorporated into honeycomb to fabricate two high-traffic floor panels. These panels have face sheets with improved adhesion to the honeycomb core to minimize any delamination problem. These two panels have been installed in two United Aircraft 747 airplanes for flight tests.

An aircraft manufacturer and an aircraft materials supplier are optimizing the Fluorel laminates with regard to the Fluorel core thickness in relation to the various weights and types of face skins. The objective of the program is to obtain lighter weight wall and ceiling panels without sacrificing any of the acoustical properties.

Figure 1.— Post-crash external fuel fire aircraft seat flammability test.



Toxicity Testing and Evaluation of Candidate Aircraft Material

As a part of NASA's fire retardant materials engineering program (FIRE-MEN) at JSC, the applicability of procedures commonly employed in behavioral pharmacology research to material toxicity tests has been investigated. These procedures are based on techniques developed in operant behavior technology. The advantages of these techniques to material fire tests are that objectively quantifiable changes in behavior can be monitored during tests and related to changes in the off-gassed products produced during material pyrolysis and/or combustion. In addition, these techniques allow the sensitivity of different behaviors as test biological end points to be compared and evaluated. For instance, laboratory tests at JSC have shown that rodent operant bar pressing for shock escape is more resistant to carbon monoxide induced incapacitation than is ambulation in a rotating wheel. Such results indicate that conclusions about the absolute behavioral toxicity of materials would vary with the particular biological end point employed in the test procedure.

The results of a JSC material toxicity test in which operant shock escape behavior served as the biological end point is illustrated in figure 1. The materials tested were a conventional fire retarded polyurethane foam and a recently developed polyimide foam. At each of three temperatures, the effects of the pyrolysis products of the two polymers were determined. As the figure indicates, behavioral toxicity varied with test temperature and toxicological rankings of the materials based on either the higher or lower test temperature alone would have differed.

In addition to laboratory tests of polyimide and polyurethane foam, full-scale tests of materials were conducted in the JSC 737 fuselage. Two indices of material toxicity were gathered during these tests: (1) 24-hour mortality tabulations and (2) changes in operant shock escape performance. The materials tested included seating forms and upholstery, wall and ceiling panels, storage bins, and passenger service units. The volume of fuel used for material igni-

tion and fuselage ventilation rates were varied during these tests to help determine the contribution of these variables to cabin fire toxicity. The results of these tests indicate that larger fuel volumes and polyurethane seating foams significantly increase the toxicity of a cabin fire.

Figure 2 shows the operant behavioral data from full-scale tests of contemporary polyurethane seating foam, ceiling and wall panels, and new state-of-the-art polyimide foam

and paneling. These results are encouraging for the increased safety provided by the new materials. At no point during the test of the state-of-the-art materials was behavioral incapacitation evident, indicating a significantly reduced toxicity hazard for the new materials. Based on these tests, the new polyimide foam appears to hold great promise as a fire retarded seating material for use in public transportation vehicles.

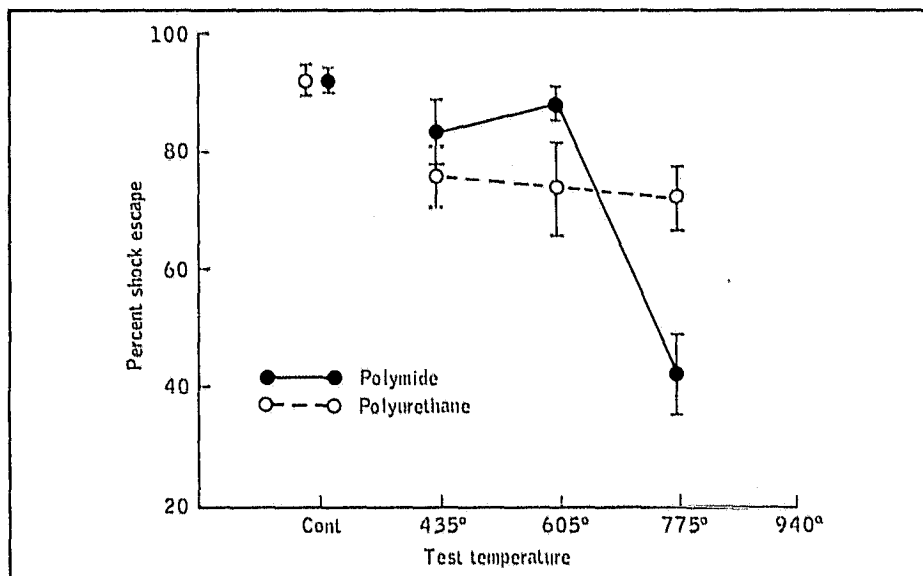
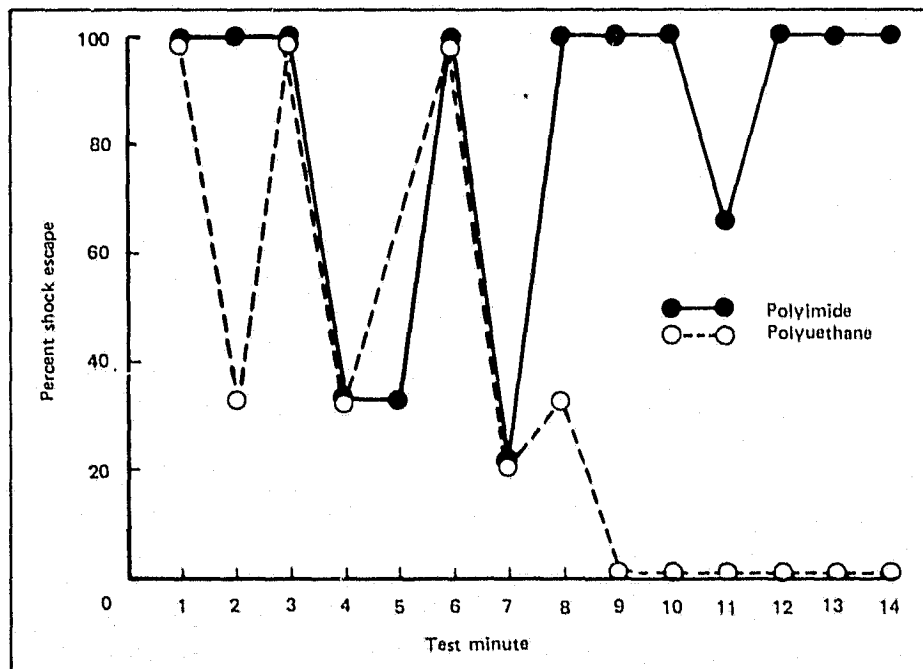


Figure 1.— Mean percent shock escape (\pm 1 standard error) as a function of pyrolysis temperature and test material.

Figure 2.— Percent shock escape as a function of test time and test material.



Space Operations Center Technology Assessment

The Space Operations Center (SOC), in its total concept, will provide the means to accomplish space endeavors well beyond the technical capability and experience now existing in the United States space program. The SOC, from its initial permanently manned capability through its evolutionary growth to a large space system construction facility and space vehicle servicing facility, presents a number of technological challenges and opportunities.

The acceptance of the SOC as a credible program demanded that a critical assessment be made of the application of state-of-the-art technologies and the benefits to be derived from technology improvements. In the latter category would be, for example, closed-loop life support systems to reduce dependence upon resupply of expendables, high voltage power systems to reduce weight, and optical information transfer busses to reduce weight and minimize electromagnetic interference problems. While the initial SOC configuration could be developed by using conventional technologies, improvements such as those cited could potentially provide a more capable facility and avoid built-in obsolescence.

With the identification of potential technology improvements, it is then necessary to develop an overall technology advancement plan which, when implemented in the early phase of the program, will assure that development and schedule risks are minimized.

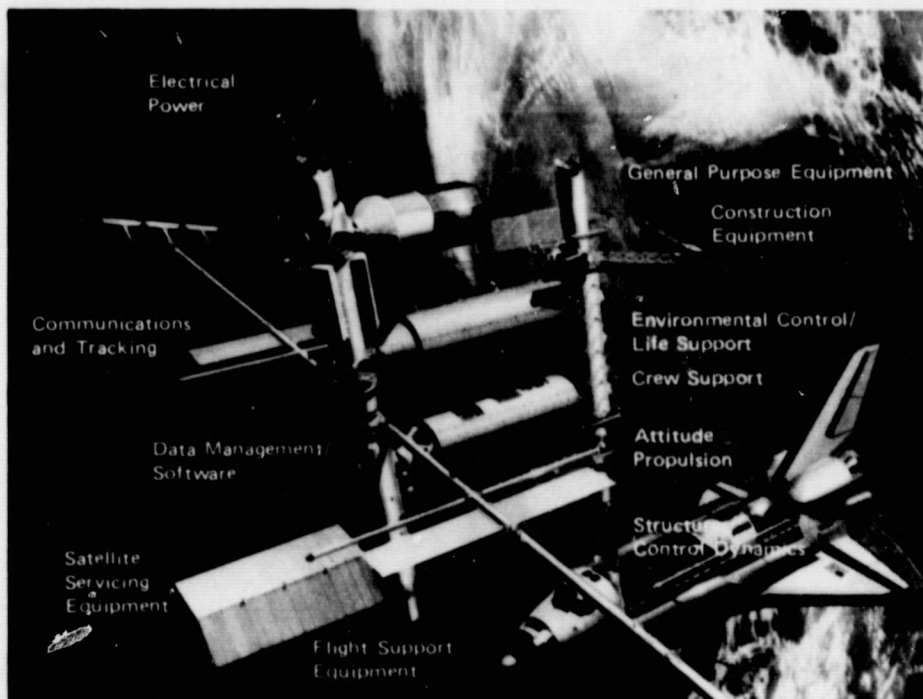
The approach taken was to structure a technology assessment task to be placed with the prime study contractor. The task was to be treated and analyzed as an integral part of the overall study and concept definition activity with the necessary iterations and interactions with the overall concept definition and analysis tasks. The end product of the task would be used as supporting data to be integrated with a SOC technology advancement plan to be developed at JSC.

The contractor examined 11 technology assessment areas (fig. 1) in the course of the study. Individual assessments were made for both the initial operational configuration and the growth configuration with capabilities for large space-system construction and orbital-transfer vehicle servicing. While no technology "break-throughs" were identified as required, a total of 54 specific technology improvement items were identified. For each item the contractor assessed the criticality/priority level, the current technology level, and the technology readiness level the specific item should attain prior to the preliminary design review of the detailed design and fabrication phase of the program.

The contractor data are now being integrated into the SOC technology advancement plan at JSC. Formal publication is expected late in calendar year 1981.

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Figure 1.— Space Operations Center technology assessment areas.



Space Sciences

Office of Space Sciences

Summary

Lunar and Planetary Sciences

During fiscal year 1981, planetary sciences at the Johnson Space Center (JSC) continued a broad range of experimental and theoretical investigations. Different investigations focused on virtually every class of planetary object that displays a solid surface. During 1981 as in previous years, the overall thrust of planetary research projects at JSC was unified in sample-oriented research. The ability to properly store, prepare, and analyze samples of planetary interest is what sets JSC apart from other NASA centers in planetary studies.

Great advances were made at JSC during the past year in several areas of interest to planetary scientists. Some of the most outstanding contributions are summarized in the following

paragraphs, and others are described in the section of this report on significant tasks.

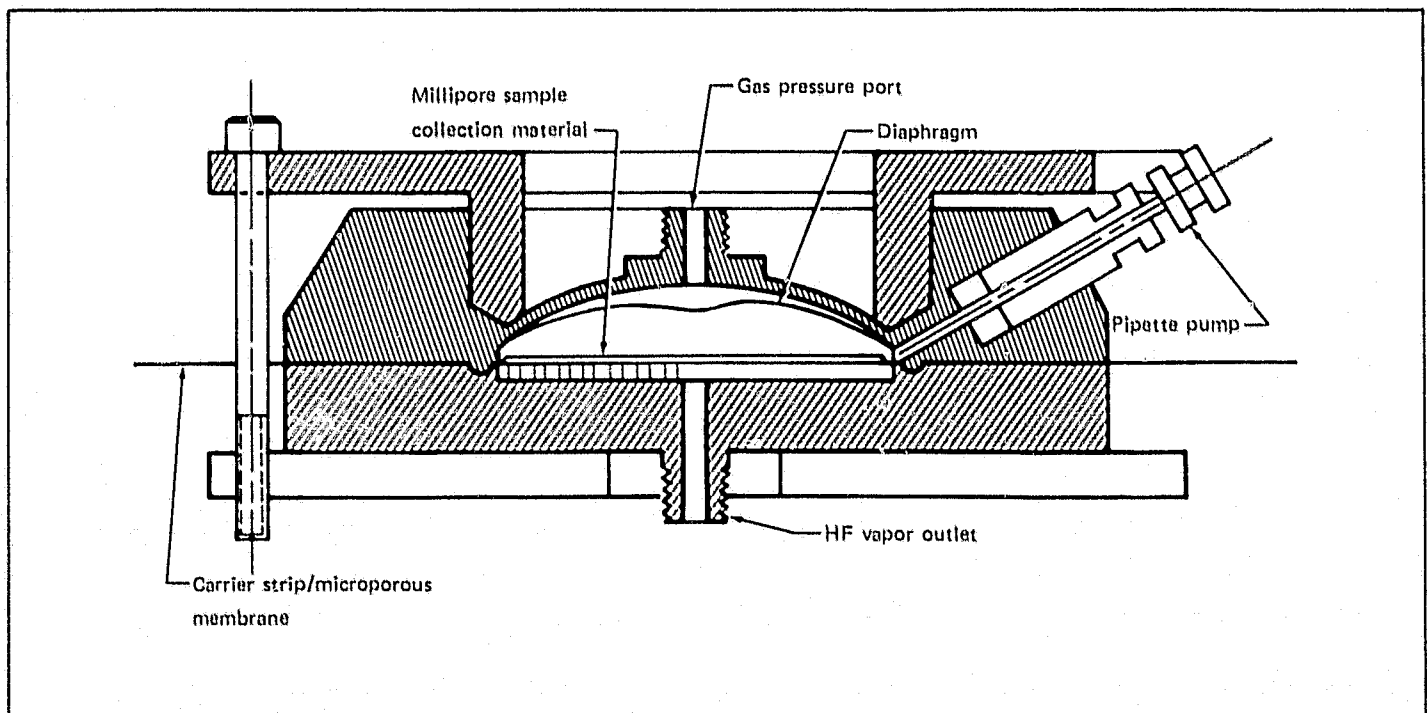
Technology

Technology is discussed first in this summary because of the significance of the new cosmic dust collection system that is now in operation. Development of a new cosmic dust collector has been in progress for several years. A new set of collectors has been completed and is now flying and collecting cosmic dust. The new collectors have the potential to increase the world's collection of cosmic dust by orders of magnitude. The availability of this new, greatly enlarged collection of cosmic dust grains will surely open the way to fascinating new research on these

materials. Future analytical investigations of these materials may well provide insights into the early condensation of the solar system.

Another technology thrust concerns direct analysis of cometary dust by spaceborne instrumentation. A study of the feasibility of collecting cometary dust and performing isotope dilution by mass spectrometry of the collected materials is being performed. The research plan is to consider the potential instrument, one component at a time, and develop a functional design for each component. In the past year, a new design was developed for a sample canister (fig. 1). The sample canister is now in fabrication. After fabrication, each component will be laboratory tested in an end-to-end mode to determine if the component operates properly.

Figure 1.— Design concept for the sample canister. Material to be analyzed is collected on the millipore sample collection material. That material is carried on the carrier strip with the microporous membrane that is used for liquid-vapor phase separation. The diaphragm is manipulated with GN_2 pressure to control liquid in the sample canister.



A third major technology thrust in planetary studies concerns an ion microprobe microanalyzer. This type of instrument, when developed and operating, will make it possible to analyze planetary materials for a wide range of major and trace elements for isotope abundances and ratios. The instrument allows those analyses to be performed with a spatial resolution of 10 micrometers or less. It is essential to recognize that minerals and other planetary materials are not homogeneous on the 10-micrometer scale, and the differences from homogeneity contain information on the history of the planetary materials. This technology may bring about a great leap forward in understanding planetary materials and hence planetary history. During this past year, JSC has advanced toward obtaining a new ion microprobe mass analyzer by defining achievable, state-of-the-art specifications.

Lunar Studies

As in previous years, lunar studies accounted for about one-third of the planetary research performed by JSC. Many of these studies concerned individual lunar samples and details of each rock's mineralogy, petrology, geochemistry, and/or isotopic composition. Such studies were performed on soil and rocks from the lunar highlands. One particularly comprehensive study involved Apollo 15 core sample 15008. This sample was opened, dissected, and distributed to investigators as part of a continuing project to systematically open all returned Apollo cores. Numerous samples of 15008 were studied in the laboratories at the JSC. Whereas in previously opened cores there have been distinct layers with a range of mineralogy, chemistry, exposure age, and maturity, the data for 15008 displayed very little change in parameters as a function of depth.

An observation that received much attention at the recent Lunar and Planetary Science Conference was that the suite of lunar plutonic rocks differs from one Apollo landing site to another. This observation was recognized and published by JSC scientists in the mid 1970's. Their data showed that anorthosites are common at the Apollo 16 site and that norites and

troctolites are common at the Apollo 17 site. The idea was not well received at that time because the current model of the Moon was that it consisted of shells. But in the past year lunar science had advanced so that models with lateral heterogeneity were being considered. Thus, the differences between the Apollo 16 and 17 landing sites became supporting information for the concept.

Asteroid Studies

The proper interpretation of reflectance spectra obtained from asteroids and other planetary objects is one of the studies at JSC. The approach is to obtain laboratory spectra of likely planetary materials. These model spectra will then be available to interpret planetary spectra obtained telescopically. The great advance this year was totally unexpected. Laboratory spectra collected on materials as a function of grain size demonstrated that grain size is a major parameter in determining the final reflectance spectra. It was demonstrated that grain size is a more important parameter than admixtures of "lightening" or "darkening" agents (i.e., minerals) such as plagioclase and ilmenite. Laboratory experiments demonstrated that the absorption

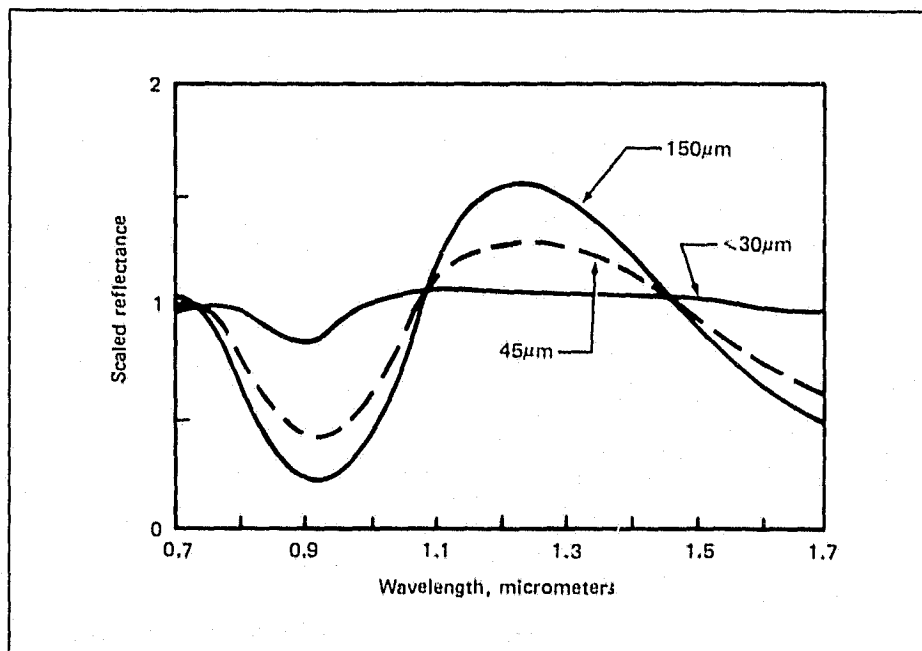
bands in pyroxenes became less deep with decreasing grain size (fig. 2). This effect is so strong that grain sizes less than 30 micrometers yield spectra that are almost flat, especially compared with spectra obtained on samples with grain sizes over 150 micrometers.

Earth's Ancient Crust

Studies of the rare-Earth-element isotopes of samarium (Sm) and neodymium (Nd) have been conducted on terrestrial anorthosites from Bad Vermillion Lake (Canada) and Adirondack Mountains (N.Y.). The techniques developed for planetary sample analysis allow these rocks to be dated for the first time. They are ancient (2700 million years and 1200 million years, respectively) and were derived from a source material different from that of the chondritic meteorites (a solar system standard). The application of new techniques at JSC can significantly improve our understanding of the development of the Earth's crust and mantle for comparison with the other planets.

There are two significant tasks that focus on 3300 million-year rocks from the Beartooth Mountains in Montana and Wyoming. One described the age and geochemistry of the supracrustal

Figure 2.—Laboratory reflectance spectra curves for mixtures of 15 percent ilmenite with 85 percent enstatite. The absorption band near 1.0 micrometer is due to an Fe^{+2} transition in the enstatite. Decreasing grain size may cause the absorption band to lose its intensity.



sequence of volcanic and sedimentary rocks that were dated. The second described the metamorphism of those rocks as taking place at 650 to 750° C and between 5 and 7 kilobars. The result demonstrated significant thickness of continental material already separated from mantle at 3300 million years. To be metamorphosed at 5 to 7 kilobars directly implies a depth of burial of between 16 and 22 kilometers. And since the volcanic and sedimentary sequence was deposited and derived in part from pre-existing continental material, there must have been significant thickness of continental material in the form of continents. Thus, the ideas of some scientists that the early Earth could not support thick continents must be incorrect.

Mars and Venus

The major research this past year was weathering on Mars. The dry valleys in Antarctica continue to provide martian weathering analog materials. These materials have been analyzed for mineralogy, petrology, bulk chemistry, and volatile gases. The model for an ideal Antarctica weathering profile (fig. 3) developed from JSC research has greatly aided in the interpretation of Viking data from the Mars surface.

High contents of chlorine and possibly sulfur in the Viking analysis of Mars soil may be understood in terms of enrichments due to weathering. In addition, the duracrust on the surface of Mars may be due to a surface layer of cemented soil as a natural weathering phenomenon. This research, combined with the JSC investigation of the effects of ultraviolet (UV) and infrared (IR) on the weathering of martian minerals reported last year (tests indicate that IR is important but UV is not) is causing a major change in the understanding of weathering on Mars. This understanding is particularly important for any future landing mission to Mars. The nature of the surface must be understood to properly plan surface activities of sample collection (for return to Earth) and of in situ analysis.

Comets

One investigation of comets during the past year indicated a 29-year periodicity for falls of H-chondrite meteorites with 3- to 5-million year exposure ages. A 29-year periodicity is suggestive of a comet-type origin for the parent body of the H-chondrites. This is interesting and important because the H-chondrites with 3- to 5-million year exposure ages represent about 20 percent of all known

meteorite falls. If all the investigated H-chondrites have a similar orbit for their parent body, perhaps there is but a single parent body for these 20 percent of all known meteorites. This implies that very few parent bodies are represented in our meteorite collections, and their parent bodies are in comet-type orbits and not in asteroid-type orbits.

Basaltic Volcanism

The basaltic volcanism project is now completed. Several JSC scientists participated in this program dedicated to writing a book on the role of basaltic volcanism in planetary development. As an important portion of the project, hundreds of major and trace element analyses of selected suites of basalt samples from around the world were performed in our laboratories. These samples were selected to represent numerous types of basalts — both tectonic types and compositional types. These analyses will form the basis for much statistical research in future years.

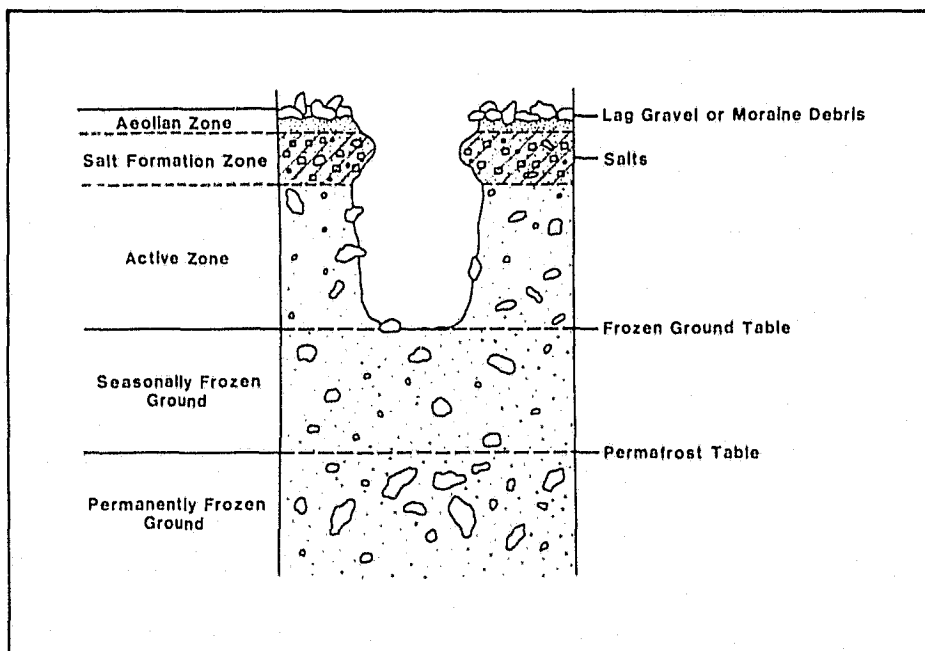
Cosmic Dust

Cosmic dust was only recently identified and verified as being extraterrestrial. As noted in the section of this summary on technology, the Curator's Office at the JSC recently initiated a program of cosmic dust collection. The first samples of the newly-collected cosmic dust should be in our laboratories at this time. The electron microscope laboratory at the JSC is newly-instrumented with a transmission electron microscope specifically designed to study the mineralogy, petrology, and crystallography of these cosmic dust particles.

Icy Satellites and Asteroids

Studies of photography obtained by Voyager spacecraft are being conducted at JSC. Large, multiringed basins on these icy objects, such as the Valhalla Basin on Callisto, the 4th satellite of Jupiter, show morphological features similar to structures known on Earth from glacial and ice-covered regions. Specifically, the Valhalla Basin has been modeled as an ice cauldron due to internal collapse.

Figure 3.— Idealized soil profile from the Dry Valleys of Antarctica which is applicable to the Martian regolith. Most of the chemical alterations and secondary mineral formation occur within or above the active zone. The vertical scale or depth may vary depending upon the local environment.



Meteorite Studies

Meteorites from Mars and fluid inclusions in meteorites were two studies that received public attention the past year. An additional study sets out a new model for chondrite formation.

Meteorites from Mars is highlighted as one of the significant tasks. A group of nine known achondrite meteorites have characteristics best explained by the idea that they originated on Mars. The most direct evidence is that these meteorites are igneous rocks that crystallized about 1300 million years ago. This means that their parent bodies had to be heated to melting 1300 million years ago or about 3000 million years after formation of the parent bodies. Not understanding how an asteroid could stay hot so long, attention was directed to the planets in the search for a parent body. The

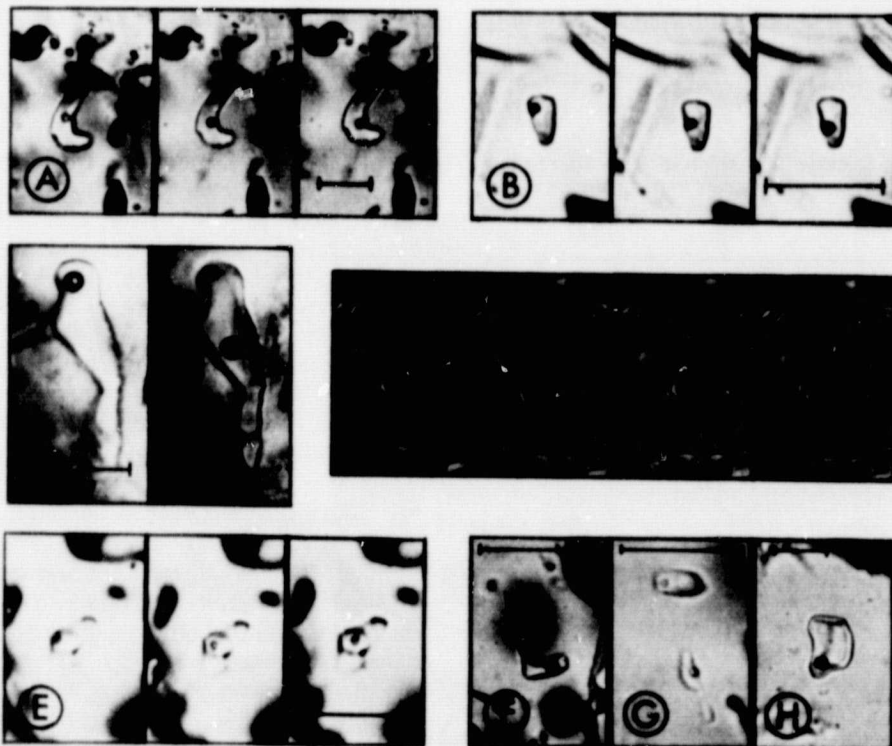
geochemical characteristics of these nine meteorites do not match either Earth or Moon, so those planets are not the parent bodies. On the basis of the high density of impact craters on its surface, Mercury was not volcanically active at the proper time. Venus was considered but it is so large that it is difficult to remove the rocks from its surface. So Mars is the best candidate for the parent body. Its gravity is low (38 percent of Earth's) so it is less difficult to account for the removal of rocks, and there are volcanoes on Mars that appear to be geologically young. The identification of these meteorites from Mars allows speculation about the mantle of Mars as well as its thermal history.

Fluid inclusions in meteorites is a new field, and there are only two or three previous reports about them. Scientists at JSC have identified fluid

inclusions in an achondrite meteorite (fig. 4). An analysis of the fluid contained within the inclusion is important in determining the chemical composition and density of the vapor phase that was present during formation of the host mineral. Because volatiles are so important in rock formation, these direct samples of ancient fluids provide important constraints in the history of planetary samples. In the case of this meteorite, the fluids are high-density aqueous solutions of sodium chloride and indicate that the meteorite formed on a very large parent body — perhaps a very large asteroid or even Mars.

A new model for chondrites received much attention during the annual Lunar and Planetary Science Conference. This model, by a JSC scientist, suggests that chondrites form by accumulation of chondrules that formed through collision of partially molten planetoids. This model accounts for the textures of chondrites as well as for the peculiar shape and texture of chondrules. The purpose of the new model is to identify energy sources for the formation of chondrules. Specifically, the new model is in accord with surface tensions recently measured in our laboratories for silicate liquids.

Figure 4.— Photomicrographs of fluid inclusions in meteorites. The scale bar in each photo is 10 micrometers long. In a, b, c, d, and e, a single fluid inclusion is shown in several views. In each view a vapor bubble may be seen in the inclusion. The vapor bubble is in a different location in each photograph. The difference in the location of the vapor bubble is evidence that the material in the inclusion (the host of the vapor bubble) is a liquid. Views f, g, and h illustrate different inclusion shapes.



ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Life Sciences

During fiscal year 1981, with the successful Space Shuttle mission(s), Life Sciences has moved from a strictly research mode, as experienced during the interval from the last manned U.S. flight to the STS-1 flight, to a dual research and operations mode. JSC conducts a broad range of medical research and operations activities in support of the following Life Sciences Program goals:

1. To ensure the long-term health, well-being, and performance of humans in space; to characterize the medical constraints of space flight; and to enable participation by a broader segment of the population.

2. To use the space environment as a laboratory for furthering fundamental knowledge in medicine and biology.

3. To conduct the research and technology development necessary to maintaining life in space on a self-sustaining basis for long periods of time.

4. To understand the origin and early evolution of life on Earth, its relationship to its habitat, and the potential for the occurrence of life elsewhere in the universe.

To accomplish these goals, activities at JSC, funded by the Office of Space Sciences, involve research and technology development. The major activities in research during fiscal year 1981 were directed to the goal of ensuring the long-term health, well-being, and performance of humans in space. An in-house JSC effort has produced a Medical Information System to provide medical operations personnel, supporting laboratories, and management timely methods to collect, store, retrieve, manipulate, summarize, and status all elements of medical information on each crewperson. In addition, research has been conducted into the effectiveness of denitrogenation procedures on space crewmembers to avoid the hazards of decompression. A microprocessor-based physiologic instrument has been developed to provide a bedside arrhythmia monitor. The system is capable of receiving electrocardiographic input from a human subject and categorizing each beat as normal or abnormal. The system does not replace the need for a human monitor,

but it does provide precise quantitation and data storage. A major technology effort to apply Image Enhancement techniques to evaluate damage to human cells was completed during fiscal year 1981. This technique will enable scientists to examine and quantitate heretofore undetectable cellular changes.

Activities in technology development include the following.

1. An anthropometric measurement system incorporating a computer-aided design system has been developed for designing work stations and living quarters for use in space. Design problems previously requiring expensive mock-ups can be avoided by using this system that can access descriptions of the astronaut population and make them available to design engineering from the preliminary design stage to final stages

2. Six Degree-of-Freedom Hand Controller - feasibility of testing is underway for the development of a six-degree-of-freedom hand controller system. Previously, spacecraft crewmembers had to use two three-degree-of-freedom controllers that required the use of both hands to operate. The new six-degree-of-freedom controller will free one hand for other necessary operations.

3. Wash Water Renovation - a breadboard system has been developed and tested to renovate used wash water for long-duration missions, thereby minimizing the water storage requirement.

4. Biocidal Ion Exchange - a biocidal ion exchange system has been developed to provide positive control of microorganisms in spacecraft potable water systems without the involvement of crewmembers.

Figure 5.— Cell image enhancement.



Office of Space Sciences

Significant Tasks

61 Cosmic Dust Collection

Funded By: Planetary Materials (UPN-152)
Technical Monitor: U. S. Clanton/SN6
Task Performed by: Lyndon B. Johnson Space Center

62 Evidence About The Early Earth's Crust

Funded By: Planetary Materials (UPN-152)
Technical Monitor: L. A. Nyquist/SN7
Task Performed by: Lockheed Engineering and Management
Services Company, Inc.
Contract NAS 9-15800

63 Shock Induced Melting in Dense Versus Porous Media

Funded By: Planetary Geochemistry and Geophysics (UPN-153)
Technical Monitor: F. Hörz/SN6
Task Performed by: Lyndon B. Johnson Space Center

64 A New Model for the Origin of Chondrites

Funded By: Planetary Geochemistry and Geophysics (UPN-153)
Technical Monitor: H. A. Zook/SN6
Task Performed by: Lyndon B. Johnson Space Center

65 Metamorphic Petrology in Archean Supracrustals

Funded by: Planetary Geochemistry and Geophysics (UPN-153)
Technical Monitor: J. L. Warner/SN7
Task Performed by: Lyndon B. Johnson Space Center

66 Spectra of Minerals and Planetary Remote Sensing

Funded by: Planetary Geochemistry and Geophysics (UPN-153)
Technical Monitor: W. W. Mendell/SN6
Task Performed by: Lyndon B. Johnson Space Center

68 JSC Extraterrestrial Microanalytical Facility

Funded by: Planetary Instrument Development (UPN-157)
Technical Monitor: C. Meyer/SN7
Task Performed by: Lyndon B. Johnson Space Center

69 Experimental Trace Element Geochemistry

Funded by: Planetary Geochemistry and Geophysics (UPN-153)
Technical Monitor: G. A. McKay/SN7
Task Performed by: Lyndon B. Johnson Space Center

70 Medical Information Systems

Funded by: Life Sciences (UPN-199)
Technical Monitor: E. C. Moseley/SD
Task Performed by: Ford Aerospace and Communications
Corporation
Contract NAS 9-15014

71 Decompression Hazards in Space Crews

Funded by: Life Sciences (UPN-199)
Technical Monitor: D. J. Horrigan/SD3
Task Performed by: USAF - School of Aviation Medicine
Contract T-82170

72 Image Enhancement Techniques Used to Evaluate Damage to Human Cells

Funded by: Life Sciences (UPN-199)
Technical Monitor: G. R. Taylor/SD4
Task Performed by: Northrop Services, Inc.
Contract NAS 9-15425

73 Biocidal Ion Exchange

Funded by: Life Sciences (UPN-199)
Technical Monitor: R. L. Sauer/SE3
Task Performed by: UMPC/JA Research Company
Contract NAS 9-15709

74 Water Recovery System for Spacecraft

Funded by: Life Sciences (UPN-199)
Technical Monitor: H. E. Winkler/EC3
Task Performed by: Hamilton Standard
Contract NAS 9-15471

75 Six-Degree-of-Freedom-Hand Controller

Funded by: Life Sciences (UPN-199)
Technical Monitor: M. M. Thomas/EW5
Task Performed by: Lyndon B. Johnson Space Center

76 Anthropometric Measurement System

Funded by: Life Sciences (UPN-199)

Technical Monitor: B. Woolford/EW5

Task Performed by: Southwest Research Institute
Contract NAS 9-16158

77 Microprocessor Based Physiologic Instrumentation

Funded by: Life Sciences (UPN-199)

Technical Monitor: M. W. Bungo/SD3

Task Performed by: Beth Israel Hospital
Contract NAS 9-14618

78 Regenerable Carbon Dioxide (CO₂) Removal for Portable Life Support Systems

Funded by: Life Sciences (UPN-199)

Technical Monitor: N. Lance/EC3

Task Performed by: Life Systems, Inc.
Contract NAS 9-15218

Cosmic Dust Collection

Although scientists have been trying to collect extraterrestrial particles in the atmosphere for many years by using sounding rockets and balloons, it has been demonstrated that aircraft, flying above 60 000-feet (20 km) altitude, can collect sufficient quantities of extraterrestrial particles to warrant a serious scientific program. At this altitude the incoming extraterrestrial particles are slowed (50 μm particle has a 19 cm/sec fall velocity at 20 km altitude) and concentrated ($\sim 8 \times 10^{-4}$ particles/ m^3) making it possible for high altitude aircraft to encounter approximately 0.2 particles/ m^2/sec (size $> 4 \mu\text{m}$ diameter). Some of these particles may be altered by heating during the entry process as they slow down. Particles between 5 and 100 micrometers entering at 15 km/sec may reach temperatures between 500° to 1000° C, but only for a few seconds. Fortunately, most particles do not experience the melting and vaporization that occurs with the larger meteoroids.

Although particles collected from the stratosphere include sulfate aerosols formed in the stratosphere, rocket exhaust, material uplifted from large volcanic eruptions, and debris ablated from meteoroids, in addition to pristine and altered cosmic dust, it has not been difficult to recognize cosmic dust because it apparently predominates in the > 10 -micrometer size range. It is more difficult to recognize in the < 10 -micrometer size because rocket exhaust predominates between the 1- to 8-micrometer size, and stratospheric aerosols (sulfates) predominate below 1 micrometer.

The morphology of cosmic dust is diverse and includes fluffy aggregates, dense mineral grains, spheres, platelets, crystals, etc. Sufficient quantities have been analyzed to recognize five different groups based upon elemental and mineral composition:

1. Chondritic aggregate — These particles are the predominating type and consist principally of many sub-micron crystals in aggregate form. Each aggregate has a typical elemental content of iron, magnesium, silicon, carbon, sulfur, calcium, and nickel in decreasing abundance. The minerals identified in this group are olivine,

enstatite, magnetite, pyrrhotite, and a hydrated silicate having a 7A d-spacing. The chondritic aggregates are so named because their elemental content is very similar to the bulk composition of type C1 carbonaceous chondrites (a group of primitive meteorites that best represent solar system abundances of the elements).

2. FSN — These particles occur as spheres, platelets, octahedra, and irregular crystals. Each has a typical elemental content of iron, nickel, and sulfur. The minerals commonly identified in this group are magnetite, troilite, and pentlandite.

3. Mafic silicates — These particles occur as single dense crystal grains with a typical elemental content of magnesium, iron, silicon, calcium, and chromium. The minerals commonly identified in this group include olivine and pyroxene.

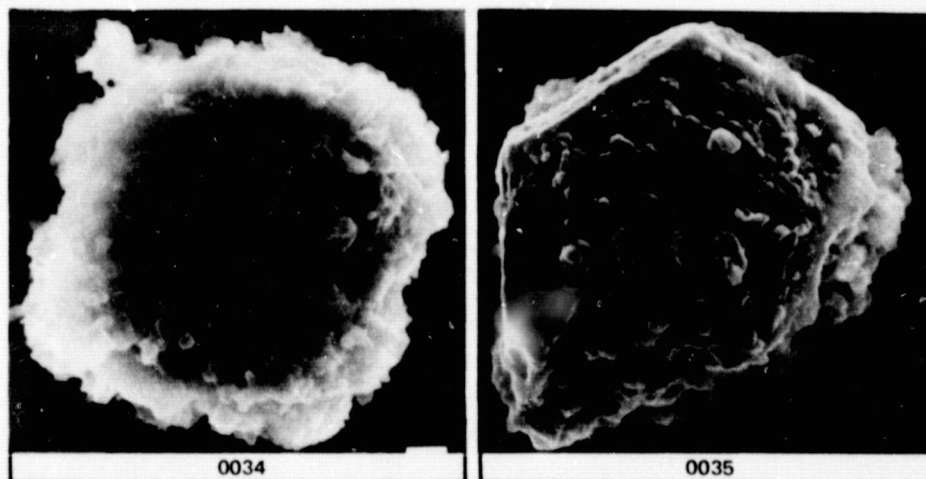
4. Iron-nickel — these particles occur as spheres and irregular crystals whose elemental content is typically iron, nickel, and sulfur. The sulfur content is low and no sulfide minerals have been identified, although taenite and wüstite (product of ablation processes found in spheres) are common.

5. Others — This category is for particles with unusual textures and shapes. Some of these particles have nickel, iron mounds adhering to a mafic silicate or chondritic aggregate particle.

Although limited quantitative analysis shows that much of the cosmic dust material resembles the volatile-rich type C1 carbonaceous chondrites, a small fraction, perhaps 10 percent, appears to have no known meteorite analog.

Johnson Space Center has begun a systematic collection and curation of cosmic dust. Collections are made at 60 000 feet by means of two pylons holding four collectors each mounted under the wing of a WB57F airplane. At 60 000-feet altitude the impactor plates are extended into the ambient airstream with the collection surface normal to the air flow. To prevent particle bounce off, the impactor plates are coated with a film of 5 by 10⁵ centistokes silicone oil. When not collecting, the impactor is shielded by a canister to prevent contamination. All handling and preparation of the collection surfaces is in a class 100 laminar flow clean tunnel. Samples will be available for investigators beginning in January of 1982.

Figure 1.— Photomicrographs obtained with a scanning electron microscope of two cosmic dust particles. Particle 0034 is a chondritic aggregate. Particle 0035 is a FSN crystal fragment. Scale bar is 1.0 μm long.



Evidence About the Early Earth's Crust

The earliest planetary development of the Earth is largely a mystery because no rocks have been found that were created during the first 0.6 AE (1 AE = 10^9 years) of Earth history. In fact, rocks dating from the first 1.5 AE of Earth history are relatively rare. The paucity of these oldest terrestrial rocks can in general be attributed to the numerous geologic processes that have been active on the Earth throughout its history that either destroy or greatly modify any rocks in the Earth's crust. Much information about the early Earth, however, can only be obtained by careful examination of the rocks created during its first 1.5 AE of development. During the last 10 years, in an effort that was greatly stimulated by finding 4.5 to 3.9 AE old crust on the Moon, the older crustal sections of the Earth have been searched for the remains of the earliest terrestrial rocks. One of the areas that has been investigated is the Beartooth Mountains which are located along the Montana-Wyoming border just north of Yellowstone National Park.

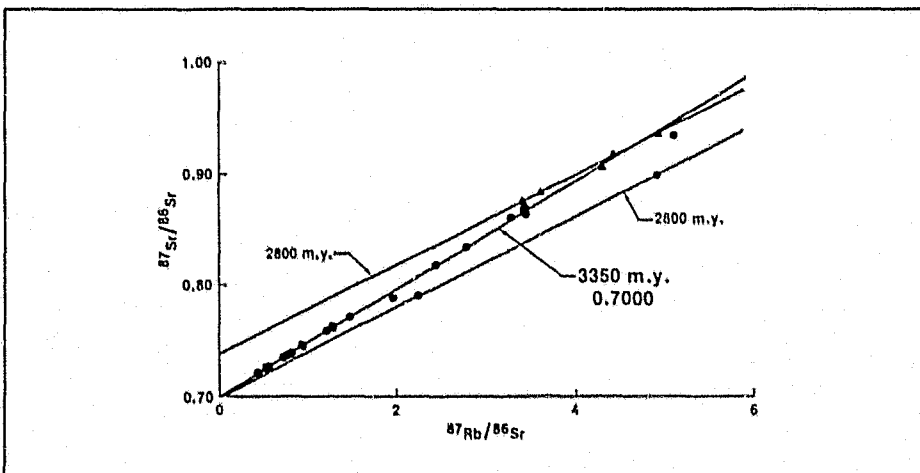
Recent geochemical and geochronological investigations of the Beartooth Mountains have revealed that the dominant rock types are several series of tonalitic to granitic intrusives that were emplaced 2.8 to 3.0 AE ago. The volume of rock emplaced between 2.8 to 3.0 AE ago was so great that the pre-existing crustal rocks in the Beartooth area were left as only widely separated remnants. These remnants vary from less than a meter to a few kilometers in size. The types of rocks found in these remnants or inclusions are quite variable and include quartzite, ironstone, meta-graywacke, amphibolite, schist, and metamorphosed felsic volcanic, and volcanoclastic rocks. All these rocks show the effects of a much more complicated metamorphic and deformational history than the 2.8 to 3.0 AE old intrusive granitic rocks. The 2.8 to 3.0 AE rocks have experienced variable grades of metamorphism but no higher grade than lower amphibolite facies. Recent petrologic work on the older crustal inclusions indicate that they have experienced an upper amphibolite-granulite grade metamorphic event that occurred at 6 to 8 kilobars of pressure. Since the rock types found in these inclusions require an origin on or close to the Earth's surface as sediments or volcanics, then at some time before 2.8 AE ago, these rocks must have been transported from the surface to depths of 20 to 25 kilometers in the lower crust.

Rubidium/strontium dating of these older inclusions indicate that they are a minimum of 3.35 AE old (fig. 1). This age is supported by samarium/neodymium model ages of 3.33 to

3.45 AE. The interpretation of the rubidium/strontium and samarium/neodymium isotopic data is difficult because these rocks have experienced a complicated geologic history involving at least two and probably three periods of deformation, metamorphism, or intrusion. On an outcrop scale, some of the inclusions had their rubidium/strontium systematics either reset or rehomogenized at about 2.8 AE ago (fig. 1). The present interpretation of data is that about 3.35 AE is the time of the upper amphibolite-granulite metamorphism or the formation age of the original volcanic-sedimentary assemblage. The timing of these two events may not differ by more than 0.05 AE and therefore not be resolvable with the strontium and neodymium isotopic data available now. The initial strontium ratio of 0.700 at 3.35 AE suggests that these rocks are not significantly older than 3.35 AE or that radiogenic ^{87}Sr was lost at that time (this may be possible during granulite facies event).

The minimum age of 3.35 AE for these rocks makes them the oldest rocks presently identified in the western United States Precambrian terrain. They are among the oldest rocks known in North America being exceeded in age only by the 3.6 to 3.8 AE old rocks of Greenland and Labrador and the 3.5 to 3.6 AE old rocks of the Minnesota River Valley. If the 3.35 AE age is a formation age, it would indicate that crustal growth during the 3.8 to 2.6 AE period was continuous rather than episodic. The geochemistry of the oldest Beartooth rocks is poorly known at present but is sufficient to show that highly evolved granitic rocks are present with trace element patterns more like those of modern island arc rocks than those of the typical low potassium, silicic, early Precambrian rocks. The tectonic setting of the oldest Beartooth rocks is unknown but requires shallow seas and mixed mafic and felsic volcanism. The Beartooth rocks also indicate that the planetary scale processes operating on the Earth before 3.0 AE ago were highly evolved, capable of producing a wide range of rock types, and generally capable of producing geologic environments similar to those that exist today.

Figure 1 — Rb-Sr systematics of the oldest identified Beartooth rocks. The approximate 3.35-AE age of these may represent the time of their origin and/or the time of a high grade metamorphic event. The scatter of some of the data away from the 3.35-AE line is interpreted as the result of the 2.8-AE Beartooth intrusive-metamorphic event. Samples from a single outcrop on Hellroaring Plateau (triangles) appear to have been rehomogenized at about 2.8 AE and show an elevated initial Sr ratio.



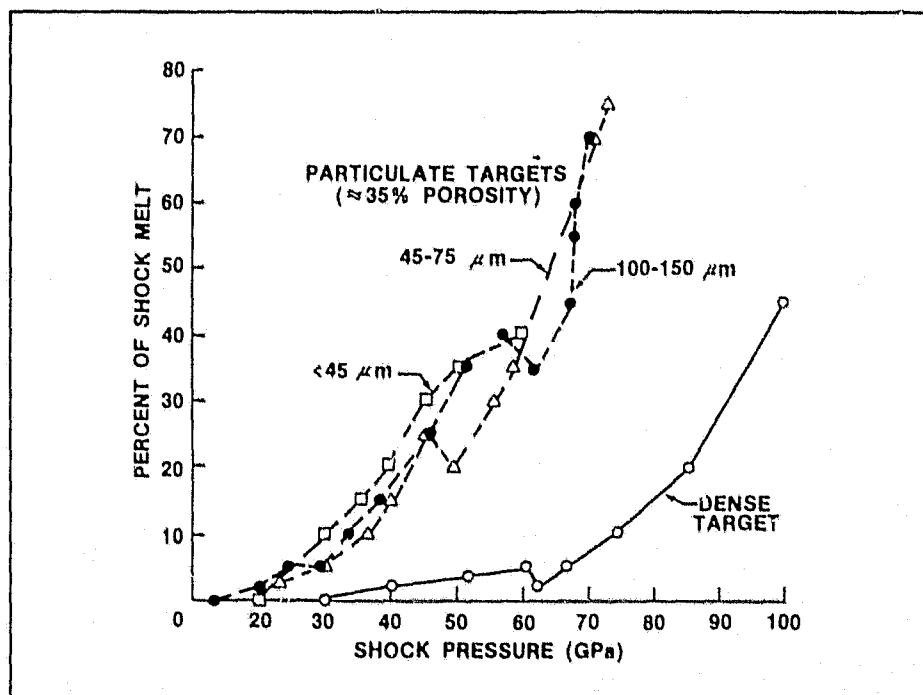
Shock Induced Melting in Dense Versus Porous Media

During meteorite impact occurring virtually on every planet surface photographed, the kinetic energy of the impact is transferred into a shock wave that engulfs the entire meteorite and propagates into the planet's surface. Generated and associated peak pressures increase in internal energy of a given meteorite volume are a strong function of impact velocity as well as density contrast between planet and meteorite materials. Natural impacts in the inner solar system have typical encounter velocities between 15 and 25 kilometers-second, that are sufficient to ionize, vaporize, and melt fractions of the excavated crater. From theoretical arguments about and practical experience gathered from nuclear or chemical explosions, it is known that overall shock attenuation and deposition of thermal energy is a strong function of target porosity. Much energy is expended in closing the void space and collapsing pores. Consider in detail the interface of a solid grain and a void space: shockwave reflects at the grain's free surface(s) and may reverberate multiple times in a single grain; the grain finally fails, and its fragments fill the pore space. The target will be at elevated temperature by the time an initially porous meteorite is compressed to its zero-porosity density. Due to highly localized stress concentrations (or lack thereof), thermal energy distribution is highly heterogeneous because of detailed grain-grain boundaries and grain-void geometries. Melting is initiated at such grain boundaries with relative ease. This melt concept was used by industry to sinter metal powders into specific shapes such as gears.

Little experimental data on the shock behavior of dense versus porous rocks exist. However, planetary surfaces are often composed of porous, fragmental materials, such as chaotic impact ejecta of the lunar soil. Therefore, a dense, nonporous lunar basalt was subjected in the laboratory to maximum shock ballistic stresses of 80 gigapascals ($1 \text{ GPa} = 10 \text{ Kbars} = 1.5 \times 10^6 \text{ psi}$). A complimentary series of experiments were conducted employing powders of various identical basalt grain sizes. Production of melt, identified in petrographic thin section, as a function of shock pressure is illustrated in figure 1. The onset of melting requires less shock pressure in the porous materials. At any given pressure, significantly more melt is present in the porous targets, and there seems to be little effect of absolute grain size.

These data will be useful in understanding the evolution of planetary impact deposits and their impact melt contents. The experiments demonstrate that lunar impact melts require collision velocities in excess of 3 km/sec, even in porous lunar soil. This, in turn, rules out the formation of impact melts by secondary impacts of ballistic crater ejecta, because ejecta velocities must be less than the lunar escape velocity ($< 2.2 \text{ km/sec}$).

Figure 1. — Production of melt, identified in petrographic thin section, as a function of shock pressure.



A New Model for the Origin of Chondrites

Near the end of the eighteenth century, a positive connection was made between certain atmospheric fireball phenomena and some rather peculiar iron or stone objects that were occasionally observed nearby. These solid objects had been picked from the ground shortly after, and close to, the occurrence of the associated fireballs. These space-derived objects are now called "meteorites" after the shooting star or "meteor" phenomena associated with them.

Because some of the meteorites were of nearly pure nickel-iron composition, it was thought that they might be fragments from the metallic core of some previously broken-up planet. Some of the stony meteorites displayed evidence that they had been derived via fractional crystallization from a molten silicate liquid. This evidence was also consistent with derivation from a fragmented planet. The general view that many meteorites originate as pieces of fragmented planets continues to be widely accepted today. The main uncertainties concern the size of the planet(s) (or planetoids) involved and the dynamics of the fragmentation process.

A particularly interesting class of meteorites are the "chondrites." Nearly all members of this class of meteorites contain numerous small, spheroidal bodies called "chondrules." It is the chondrules (which range from 0.1 to 5 millimeters in diameter) that gave rise to the name of this meteorite class. Chondrites represent about 85 percent of all meteorites actually observed to fall. The origin of the chondrules, however, and the mode of their assemblage, together with some fine grained materials into the chondrite parent bodies, continues to remain a matter of much theorizing and speculation.

A major feature of chondrites requiring explanation is the voluminous evidence that nearly all of the chondrules were once isolated, hot, molten droplets of silicate liquid. Nearly all known theories of chondrule formation include, as their centerpiece, an explanation of this feature. These theories include: (1) condensation of nebular gases directly to silicate liquid

droplets; (2) melting of isolated dust balls by lightning bolts in the early nebula; (3) planetary volcanic fire fountaining creating glassy spherules; (4) impact shock melting and dispersing of silicate solids caused when planets, planetoids, or dust balls mutually collide at very high velocities; (5) melting of nebular dust balls via heating from the surrounding, adiabatically collapsing, local nebula; (6) melting of dust balls caused by a sudden metastable-to-stable chemical transformation; (7) melting of dust balls via magnetohydrodynamic effects in the early solar system. A number of variations of the above theories have been revealed.

Problems remain with each of the above theories. Some require high early solar system nebular pressures and temperatures that cause most astrophysicists an uncomfortable feeling. Others have difficulty explaining the high volume fraction of chondrules (up to about 70 percent). And some do not lead naturally to the observed chondrule chemistry.

A new model for chondrite formation has been defined at the Johnson Space Center. The model contains the following assumptions.

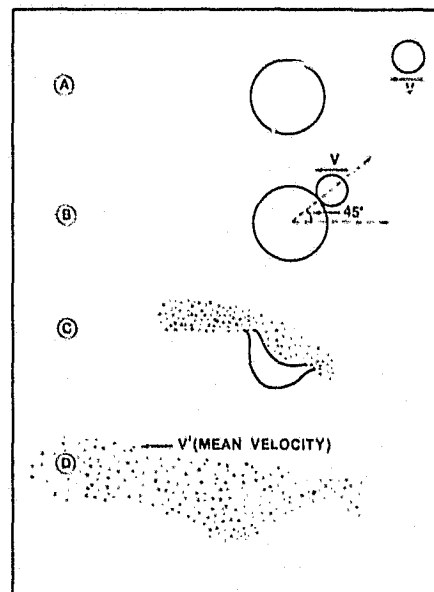
1. That, very early in the solar-system-formation process, large numbers of planetoids a few kilometers in diameter had already formed
2. That the interiors of many, if not most, of these planetoids were very hot and were molten
3. That the mutual collision rate between these planetoids was high
4. That each collision gave rise to both fragmental debris and to numerous small molten droplets (see fig. 1) — that then quickly cooled to become chondrules
5. That the chondrules and other collision debris reaccreted to form the parent bodies of chondrites. Later fragmentation of these parent bodies produced the chondrite meteorites that we now observe.

A model, or theory, of chondrite formation serves two purposes. One is that it represents an exercise, in imagination, to devise a scenario of a group of processes that could have been at work to form the chondrites that we now observe. Such a scenario should not, of course, be strongly contradicted by actual observations on

meteorites. A successful scenario, therefore, represents our best present view as to what was occurring very near to the time of origin of the solar system. The second purpose served by a good model is that it will usually predict certain experimental consequences that are not yet observed. Thus, a model stimulates new experimental meteorite research to test the model.

The model of mutually colliding, partly molten, planetoids leads naturally to the formation of molten silicate droplets that cool relatively quickly, to a high volume fraction of chondrules relative to other fragmental debris, and to certain other observed chondrite features. Some expectations of this model are continuing to be explored. The importance of the interaction between theory and experiment in testing this model can hardly be overstated.

Figure 1.— A schematic representation of a collision in interplanetary space between two internally melted planetoids.



Metamorphic Petrology in Archean Supracrustals

Knowledge of the chemical and petrologic development of some of the oldest terrestrial continental crust can greatly improve the understanding of processes which took place during the early evolution of the earth. An area that has promised to yield such information is the Archean terrain of the Beartooth Mountains of Montana and Wyoming.

The Beartooth Mountains represent one of several Precambrian basement blocks which were uplifted during the Laramide orogeny (60 million years ago) exposing a terrain composed primarily of granitic and tonalitic gneisses, migmatites, and lesser amounts of supracrustal lithologies. It is the supracrustal lithologies that have the greatest potential for providing information on the history and development of this Archean terrain. The supracrustal lithologies from several areas in the eastern Beartooth Mountains have been examined, however, most of the initial work has been directed toward the supracrustals of the Quad Creek area.

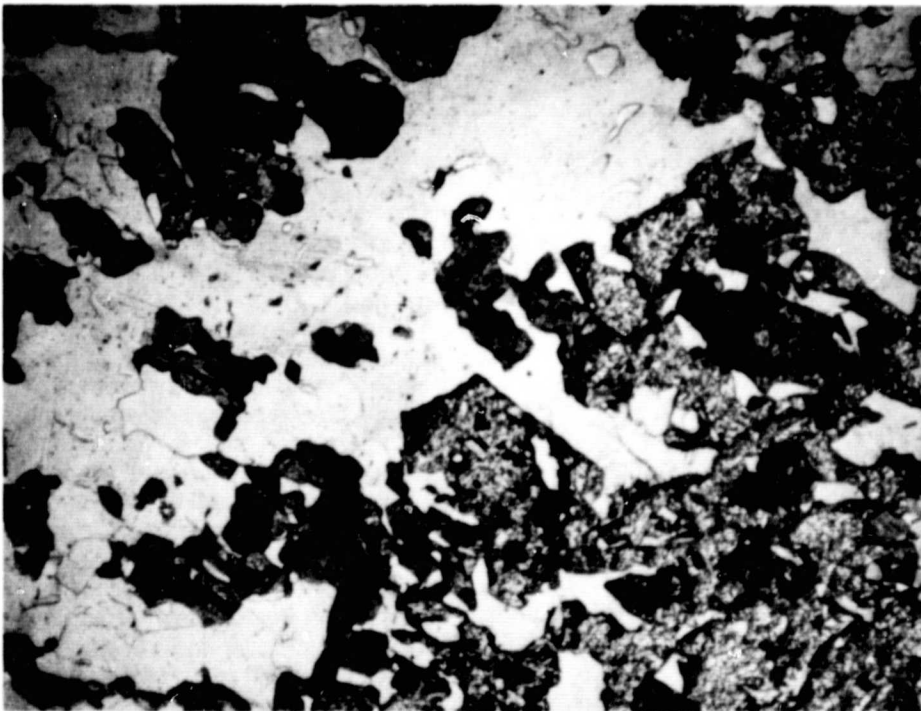
The Quad Creek area contains supracrustal lithologies including ironstone, quartzite, metavolcanic, pelitic and semipelitic schist, and meta-ultramafic which are in fault contact with the surrounding 2800-million-year-old granites and trondhemitic gneisses. The mineral assemblages present in these lithologies are consistent with lower granulite grade metamorphism. These assemblages include hypersthene + clinopyroxene + almandine + hornblende (meta-ironstone), hypersthene + hornblende + biotite + almandine (fig. 1) (metavolcanic), cordierite + sillimanite + biotite (metapelite), biotite + almandine + hornblende (semipelite), and enstatite + olivine + hornblende (meta-ultramafic). Textural information suggests that these rocks may be polymetamorphic with granulite grade assemblages being preserved in most samples. Careful application of several mineral geothermometers indicate that the granulite grade metamorphism took place at 650° to 750° C with some minor re-equilibration during a subsequent amphibolite grade metamorphism at ~600° C. Several geobarometers in-

dicate that the pressure of the granulite grade metamorphism was 5 to 7 kilobars.

Rubidium/strontium whole rock isotopic data for the supracrustal rocks indicate an age of ~3400 million years with an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio (R_i) of 0.700. This age and R_i suggest little isotopic disturbance since the time the granulite assemblages formed. Because of the pervasiveness of the granulite grade metamorphic assemblages in these rocks, the 3400-million-year age can be reasonably taken as the time of the granulite grade metamorphism. This is the oldest documented granulite facies assemblage in the Wyoming Province and suggests a geothermal gradient of 40° to 50° C/km during the early Archean in this area.

These initial findings are important because they indicate that the early continental crust was relatively thick (greater than 16 km) in this area. A thick continental crust will have major implications on the style of tectonics early in the Earth's history. Further refinements of early crustal models can be made as more information is obtained from these early Archean rocks.

Figure 1.— Photomicrograph of a metavolcanic with the diagnostic granulite assemblage hypersthene + hornblende + almandine + plagioclase + quartz.



Spectra of Minerals and Planetary Remote Sensing

The exciting photographs returned to Earth by spacecraft exploring the solar system are examples of one type of information obtained by utilizing reflected sunlight from a planetary surface. The spectrum of the reflected sunlight also can yield compositional information. This latter resource has been exploited through a collaboration among geologists and astronomers over the past decade.

Sunlight can be absorbed preferentially at certain wavelength by common rock-forming minerals found in basalts. The key to the absorption is the content of the transition metals, iron and titanium. The wavelength position and the intensity of the spectral bands is determined by the kind of transition metal, its valence state, and its molecular environment in the crystal lattice.

Reflectance spectra taken of the Moon and of Mars were examined first for these effects. Both planets exhibited subtle absorption features that could be correlated with bands found in laboratory samples. Then the spectrum of lunar soil returned by Apollo 11 was found to match telescopic measurements of the landing site at Tranquillity Base. An absorption band at a wavelength of approximately 1 micrometer was traced to the mineral clinopyroxene as predicted from the astronomical data.

The success of the lunar observations generated an explosion of scientific activity which continues to the present day. Improvements in observing techniques have permitted reliable detection of ever more subtle features in the spectra, and the new data have encouraged more detailed laboratory studies. Planetary astronomers specializing in lunar spectrophotometry can map such geologic parameters as clinopyroxene abundance, olivine content, titanium dioxide percentage, and soil maturity from Earth-based telescopes. Observations of Mars, the asteroids, and satellites in the outer solar system are multiplying. These new spectra are not as well understood as the lunar data, but many features have been identified.

Progress in this field has come from the interaction between astronomical observation and laboratory experiment with very little recourse to the theory of diffuse reflectance. As experimental sensitivity increases, previously neglected second order processes become detectable and must be taken into account in the data reduction. The effects of Fresnel reflection, particle size variation, and changes in observation phase angle must be studied by a combination of theory and experiment.

Particle size effects have been explored by application of diffuse reflectance theory to the spectrum of an orthopyroxene powder where the particle sizes fall into a narrow range. Using equations from the Kubelka-Munk theory, the reflectance at each wavelength was converted to a ratio of the bulk absorption coefficient of the powder to the bulk scattering coefficient. This ratio is called the remission function. To a first approximation, the magnitude of the scattering coefficient can be assumed to correlate with par-

ticule size and to be independent of the wavelength of the scattered light. Thus, the wavelength dependence of the remission function is attributed to the bulk absorption coefficient. New remission functions can be calculated from the experimental result by changing the magnitude of the scattering coefficient by a constant factor along the spectrum. The Kubelka-Munk transformation can be applied to the remission functions to create a suite of reflectance spectra that represent the effects of particle size on the spectrum. Figure 1(a) shows the model or the pyroxene spectra. The curves have been normalized to unity at a wavelength of 1.02 micrometers to emphasize changes in the absorption band structure. Figure 1(b) is a similarly normalized set of experimental spectra from various particle size fractions of an enstatite. The remarkable similarity between the two sets demonstrates the predictive power of this simple theory.

In a further elaboration, the scattering coefficient was assumed to exhibit a power law dependence on wavelength. As the exponent is varied from 0 (wavelength independent) to $\Delta 4$ (Rayleigh scattering), the spectrum of the orthopyroxene develops a negative slope with wavelength. The near infrared spectrum of the dark regions of Mars also shows a negative slope. The feature initially puzzled planetologists who had not seen such behavior in lunar spectra. The infrared falloff has been reproduced using particles of basalt with oxidized coatings. The model spectra provide a caveat against overinterpretation of the experimental data. The negative slope is consistent with wavelength dependent scattering, a phenomenon that can be produced by a variety of mechanisms.

As planetary surfaces are observed at longer infrared wavelengths, the energy available from reflected sunlight diminishes, and the planet's own thermal radiation becomes detectable. At the longest wavelengths, all of the detected radiation is emitted by the planetary surface. For the Moon at the subsolar point, radiant energy from the two regimes becomes equal at a wavelength of approximately 3 micrometers. Here, the term "thermal infrared" will be used to describe ra-

diant energy at wavelengths longer than approximately 6 micrometers.

All common rock forming minerals possess significant absorption bands in the thermal infrared. The spectral structure arises from molecular vibrations in the crystal lattice of the mineral. Since the vibrational spectrum does not require special compositions, the thermal infrared spectrum is inherently richer in diagnostic mineralogic information than the visible. Nevertheless, successful exploitation of infrared remote sensing has been precluded by two kinds of experimental difficulties.

The first problem is associated with the intrinsic particulate structure of most planetary surfaces. The uppermost surface particles, which emit the detected radiation, tend to be approximately the same size as the wavelength of that radiation. The natural vibrations of the lattice molecules are affected by acoustic

vibrational modes of the particle as a whole, and the resultant emission spectrum changes subtly from the "pure" spectrum of the perfect crystal. The emission spectrum is also altered by the presence of nearby particles in a complex electromagnetic interaction. Particle size effects, nearest neighbor interactions, and thermal gradients in the particulate layer all combine to broaden infrared bands and reduce the spectral contrast.

Interpretation of thermal emission spectra has been difficult. The problem has encouraged intense theoretical development, in contrast to the situation in the field of reflectance spectroscopy. The theoretical models are not yet entirely satisfactory, but a current infusion of concepts from solid state physics has generated optimism.

The second experimental problem is the difficulty of obtaining good observational data from Earth-based

telescopes. The terrestrial atmosphere has only a few "windows" of transparency in the thermal infrared. Additionally, the low spectral contrast of the thermal-emission spectrum requires observational data with a very high signal-to-noise ratio. Attempts to measure the lunar infrared spectrum from high altitude balloons or from ground-based observatories have met with only limited success. Recently, a rapid scan Michelson interferometer has been used to obtain spectra with a 500 to 1 signal-to-noise ratio on photometric nights. Although only a small number of spectra have been collected to date (fig. 2), spectral structure is clearly seen, and there is real promise for learning more about the mineralogy of the Moon's unexplored regions.

Figure 1 — Reflectance spectra normalized to unity at a wavelength of 1.02 micrometers (a) The curve labeled $c_1/c_2 = 1.0$ is experimental data for an orthopyroxene, the rest were calculated from it by using Kubelka-Munk theory (b) Experimental spectra for four sieve fractions of enstatite

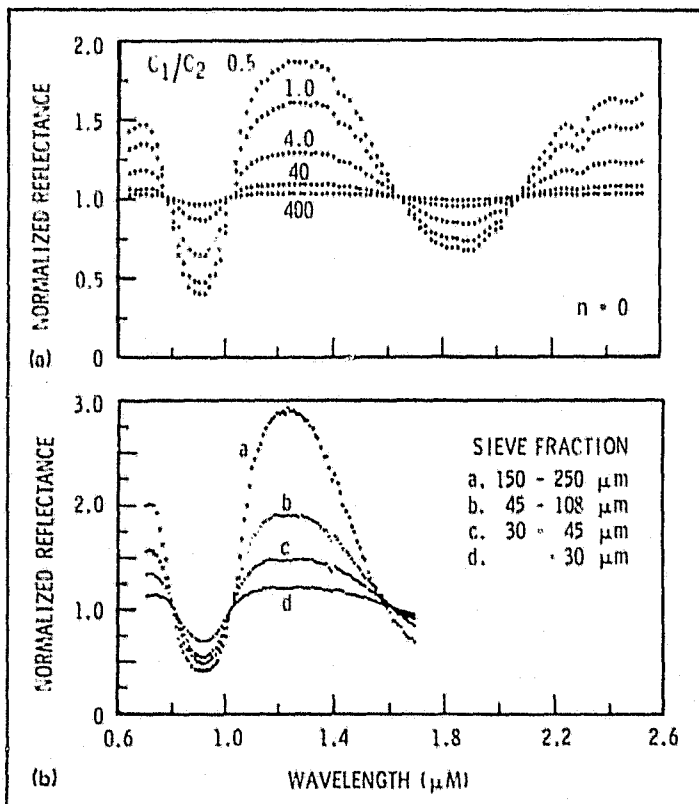
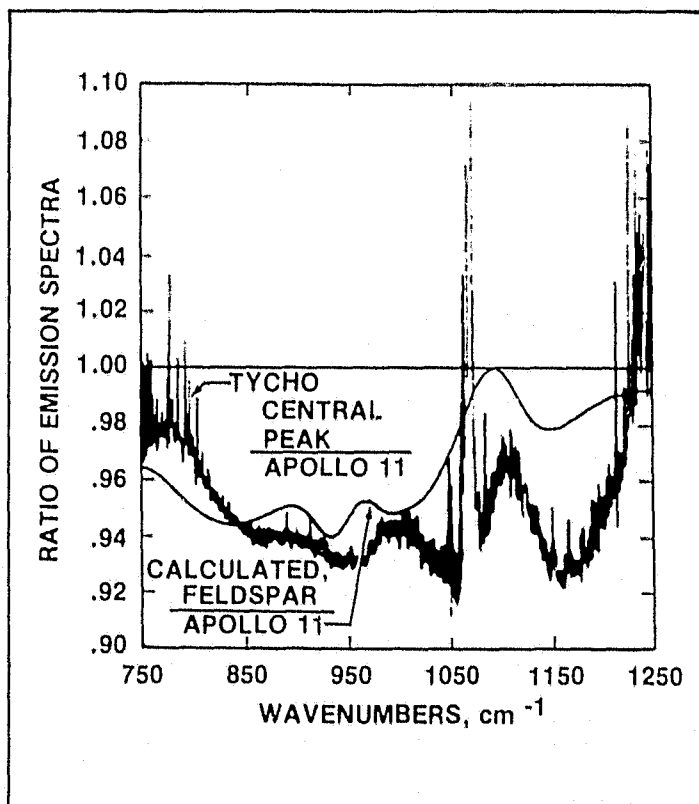


Figure 2 — Comparison of calculated feldspar ratio spectrum with an observed Tycho ratio spectrum in the thermal infrared.



JSC Extraterrestrial Microanalytical Facility

Since the Apollo lunar landing missions, great emphasis has been placed on the analysis of lunar samples. Broad scope but state-of-the-art capabilities have been established in the areas of analytical geochemical instrumentation for these purposes. One has been the direct application of the ion-microprobe technique by using a modified commercial ion-microprobe mass analyzer.

Recently, samples of meteorites and cosmic dust particles have become important to this laboratory. Ion-microprobe instrumentation of increased resolution and sensitivity are required for planned scientific investigations in at least six general areas.

1. Age determination of small rocklets from lunar soils and breccias. These include pieces of the original lunar crust.

2. Age determination of clasts in brecciated meteorites, which are thought to be samples of asteroids.

3. Trace element analysis of stratospheric dust, which is thought to contain pieces of comets.

4. Isotopic analysis of lithium, magnesium, calcium, titanium, barium, and other elements in small refractory inclusions in primitive meteorites. The inclusions are thought to be presolar grains.

5. Elemental and isotopic analysis of surface coatings of micrometeorite craters on the surface of artificial satellites returned by Space Shuttle.

6. Experimental determination of distribution coefficients for trace elements between silicate phases and melts. The results of the laboratory experiments are used to interpret compositions of basalts and the interiors of many planetary systems.

Microscopic analyses of geological specimens using ion probes represent an advanced, still evolving, analytical technique. Fundamentally, an area of a few microns in an area of a geologic sample is bombarded with accelerated, focused (primary beam) ions. Sample atoms are ionized and sputtered from the target resulting in an electro-magnetically focused secondary ion beam. A mass spectrometer then analyzes the secondary beam according to charge-to-mass ratio for counting by an ion detection system. Ion probes are 10 to 100 times more sensitive than electron microprobes used for similar studies. Instrumentally difficult areas in the development of ion probes include precise control of the electric and magnetic fields used to focus and steer the primary and secondary ion beams, and the ion discrimination and counting systems. For the past several years, JSC has successfully operated a commercial ion probe. During this period, both useful

scientific results and ion probe engineering improvements have been accomplished by JSC and visitors from other institutions.

This research team has now established technical specifications for an improved ion probe system for the JSC Microanalytical Laboratory. A new instrument that is properly configured, adjusted, and operated should provide more than an order of magnitude improvement in resolving power — the ability to distinguish closely-spaced ionic species in the secondary beam. The spot size will be as small as 3 microns or as large as several hundred microns. Depth resolution during depth profiling should be as good as 0.2 microns. Detection limits on small spots (i.e., $10 \mu\text{m}$) must be lower than 1 part per million for elements that are easy to ionize (e.g., lithium, magnesium, calcium), and isotopic analysis should be as precise as 1 part per thousand.

Unique capabilities of the required instrument include the following:

1. Direct ion imaging with high spatial resolution
2. High transmission combined with high mass resolving power
3. Energy filtering to suppress molecular-ion interferences
4. Surface analysis and depth profiling
5. Ultrahigh vacuum operation
6. Ultrastable electronics for routine operation at high resolving power.
7. Versatile, computer-controlled data collection
8. Reproducible and uniform intensity ratios from anywhere on the homogeneous sample with less than ± 0.1 percent variation.

Figure 1.— Schematic of ion optics for the ion microprobe mass analyzer.

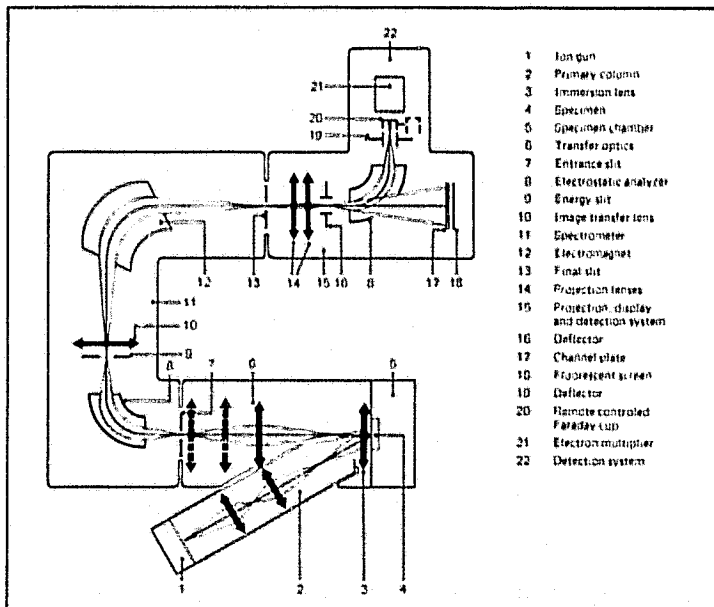


TABLE 1.— ANALYTICAL
SPECIFICATIONS FOR THE ION
MICROPROBE MASS
ANALYZER.

Ion Beam:	160° at 15 KeV
Spot size:	3 to 300 microns
Spatial resolution:	0.5 microns
Depth resolution:	0.2 microns
Mass resolution:	up to 15,000
Unique capability:	Direct ion images, Energy filtering, High transmission, Stable electronics

Experimental Trace Element Geochemistry

Igneous processes involving the production, migration, and crystallization of silicate melts are known to have been important in the formation of planetary crusts on Earth, the Moon, Mars, and some meteorite parent planets, and probably were important on Mercury and Venus as well. Such processes leave distinctive signatures in the chemical and isotopic compositions of the rocks they produce. One of the goals of planetary geochemists is to try to reconstruct the history of these processes by deciphering the chemical signatures found in rocks from planetary crusts. Some particularly useful signatures are carried in the abundances of elements that are present in most rocks in concentrations of a few hundred parts per million or less. The abundances of these "trace" elements are strongly influenced by their "partitioning" between silicate melts and rock-forming minerals in contact with these melts. Some trace elements may be preferentially incorporated into one mineral, others into another mineral, and still others strongly excluded from all minerals, and instead partitioned into the melts. Hence, a record of the history of melt-mineral interactions will be retained in the trace element abundances of resulting rocks.

One approach to using trace element abundances to unravel the history of these melt-mineral interactions is through mathematical modeling. In this approach, a plausible history of melt-mineral interactions leading to a particular sample is postulated, the effects of this history on trace element abundances are modeled, and the resulting calculated abundances are compared with observed abundances for that sample. This approach often allows certain postulated histories to be ruled out as incapable of producing samples with observed trace element abundances, and focuses attention on other postulated histories which result in good matches with observed abundances.

For use in such mathematical models, trace element partitioning between minerals and melts must be quantified. This is generally done by defining a partition coefficient, D , for each element and mineral-melt pair. D is usually defined as the weight ratio of the concentration of an element in the mineral to its concentration in the adjacent melt. In practice, distribution coefficients for many elements and minerals have not been measured. Moreover, distribution coefficients are affected by many variables in nature, such as temperature, pressure, and the compositions of the mineral and melt. The only hope of making sense

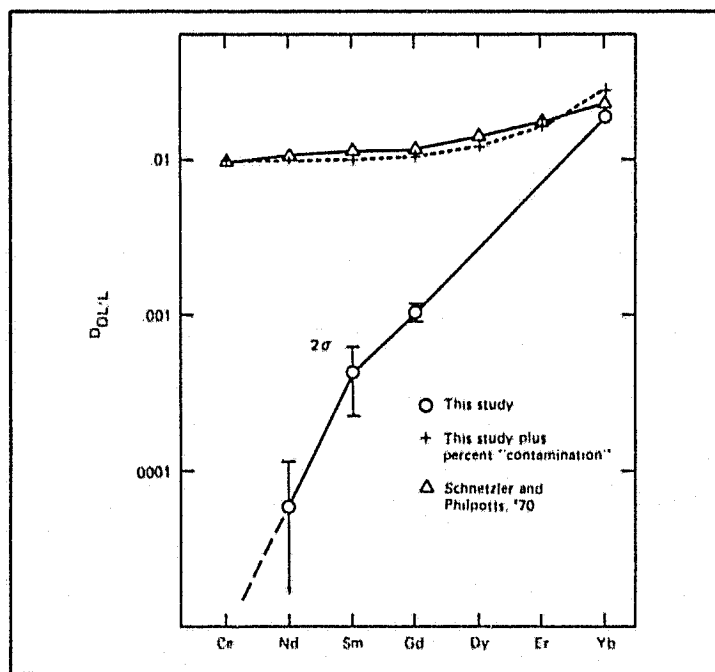
of these effects, and hence of obtaining values which can be applied to model histories of individual planetary samples, is through study under controlled conditions in the laboratory.

Recently, a program of distribution coefficient studies was started in the JSC experimental petrology laboratory. The experimental approach consists of equilibrating pertinent synthetic rock compositions at various near-liquidus temperatures and pressures, quenching the equilibrated charges to room temperature, and measuring the concentrations of the elements of interest in the resulting crystals and surrounding glass. These measurements are currently made by using special electron microprobe techniques with sensitivities of ~ 10 parts per million. The proposed new JSC ion probe facility will be used for this project in the future.

Initial work has focused on the partitioning of rare Earth elements (REE) between olivine and lunar mare basaltic melts. Results of this study are compared in figure 1 with literature values obtained from isotope dilution analyses of physically separated olivine phenocrysts and basaltic matrix. The present results for the light REE are much lower than the earlier ones, by a factor of $\sim 10^3$ in the case of the extrapolated cerium value. This discrepancy is attributed to the presence of ~ 1 percent matrix contamination in the olivine phenocryst separates in the earlier study. Apparent distribution coefficient values, which would result if olivines having as true distribution coefficients the values determined in the present study were contaminated with 1 percent matrix and analyzed in bulk, is also shown in figure 1. There is very close agreement between these "synthesized" contaminated values and the earlier phenocryst/matrix values, supporting the idea that the earlier values are strongly influenced by contamination.

Future work on this project will include measurement of distribution coefficients for other elements and minerals pertinent to the history of lunar mare basalts, lunar highlands rocks, and igneous meteorites, and use of these coefficients in mathematical models to evaluate proposed histories for these samples.

Figure 1.— Olivine/liquid partition coefficients for rare Earth elements.



Medical Information Systems

The advent of mature Shuttle operations will result in a significant increase in the number of flights, more and different types of crewmen, and varied workloads in space activities. These changes will make it difficult, if not impossible, to handle medical operational problems without increased automation. With these considerations in mind, the JSC Medical Sciences Division has been involved in implementing an automated system for assuring that all elements of medical support are available for each mission.

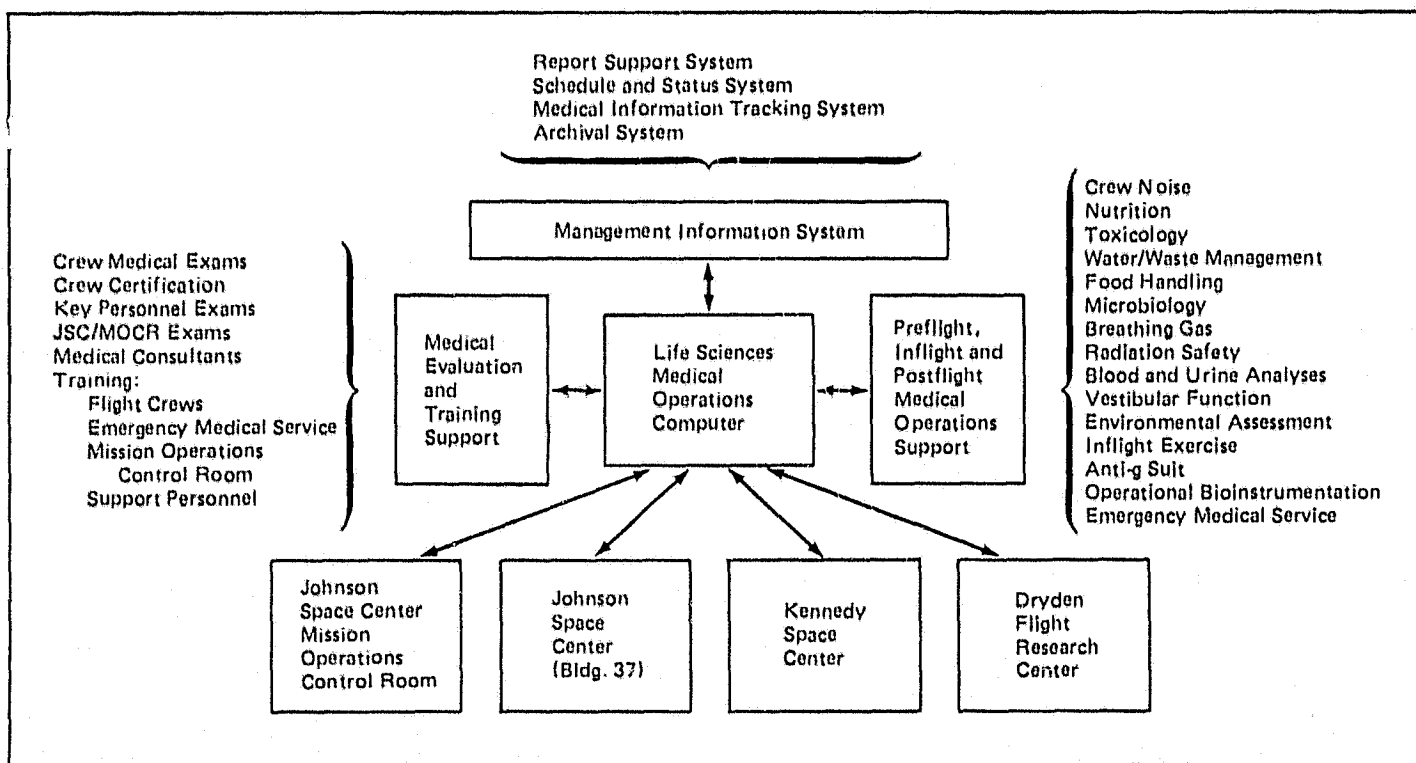
The objectives of medical operations data management are to provide medical operations personnel, supporting laboratories, and management with timely methods for collecting, storing, retrieving, manipulating, summarizing, and statusing all elements of medical support for a mission both from and to local and remote locations.

To accomplish these objectives, a centralized time-sharing computer system — called Life Sciences Medical operations Computer (LSMOC) — has been implemented along with appropriate microcomputers, remote terminals, generalized system software, and special application software. Appropriate raw and derived data, facts, impressions, and judgments are entered into this system for mission management. A generalized flow of this information is shown in figure 1.

About 10 microprocessors and 32 remote terminals collect the required medical information and forward it to the centralized minicomputer (VAX 11/70). This central system consists of storage capability (disks and tapes), printing capability, and telecommunications. In addition to the manufacturers' time-sharing programs (software), the system contains software packages to store, update, and retrieve information; complete statistical analysis; plot variables; and write special application programs. Computer programs are also available to control the access to any part of the information so that privacy of the medical records can be assumed.

The results of this system should enable NASA to provide quality and quantity of medical care with a minimum expansion of flight surgeons to meet the changes associated with many Shuttle flights.

Figure 1 — Information flow for OFT medical operations.



Decompression Hazards in Space Crews

NASA has been successful in preventing all forms of decompression sickness in space crewmembers in the past U.S. space programs. This success is considered to be due to adequate nitrogen elimination before decompression, a crew in excellent physical condition, and moderate exercise levels during extravehicular activities. During the Shuttle Program, the atmosphere of the spacecraft will be at sea level pressure (14.7 psia) with 21 percent oxygen and 79 percent nitrogen as compared to the Apollo atmosphere of 5 psia and near 100 percent oxygen. For this reason, procedures have been developed to provide nitrogen elimination from the body tissues of the crewmembers in flight immediately before extravehicular activity as compared to Apollo when it was done by breathing pure oxygen before launch.

The approach taken to avoid the hazards of decompression is to conduct research into the effectiveness of denitrogenation procedures and to propose appropriate inflight experimentation into the possible effects of null gravity on the nitrogen washout rates. From an analysis of the data, as well as that from other laboratories, optimum inflight procedures are worked out. All such decompressions are tested in altitude chambers before being used in space. Figure 1 illustrates a nitrogen elimination measurement system in the Environmental Physiology Laboratory. This system provides mass flow data on the subject's rate of nitrogen elimination. A similar system is included in a flight experiment proposed for the first life sciences-dedicated spacelab mission. Any changes observed in flight will be used to refine the bends protection procedures for future missions.

Figure 1.— Nitrogen elimination measurement system.

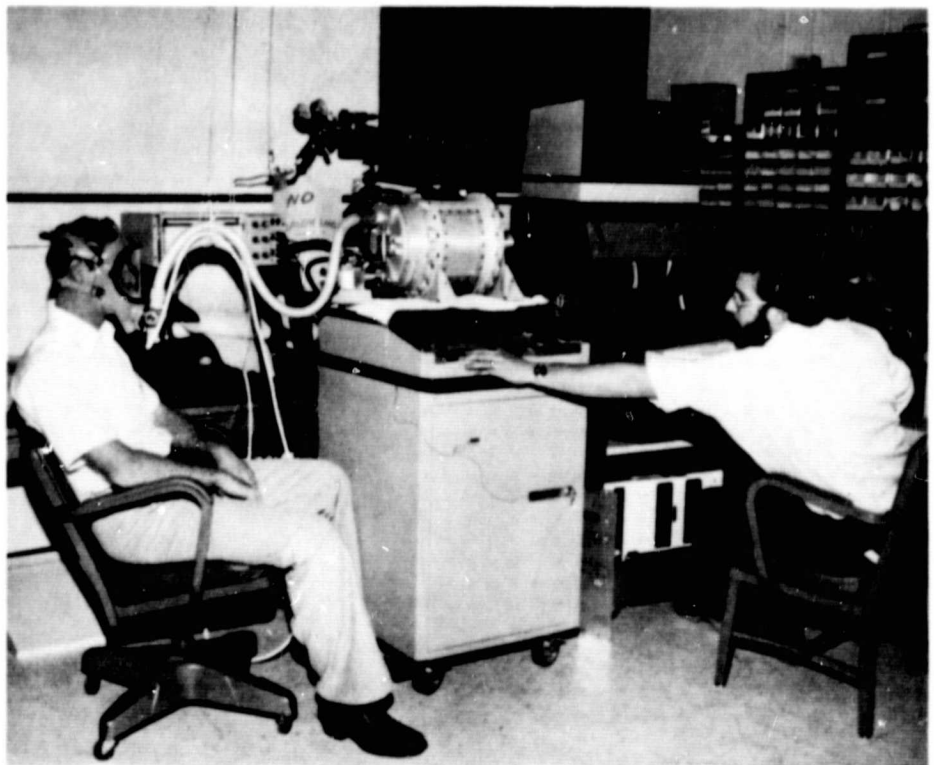


Image Enhancement Techniques Used to Evaluate Damage to Human Cells

Image enhancement is a computer-assisted technique that allows scientists to observe and accurately measure previously undistinguishable characteristics or changes in an object. An image is divided into thousands of tiny squares, and each square is given a discrete numerical value. This process has been used by the NASA to transmit pictures from distant planets. Scientists in the Cell Image Analysis Laboratory at the Johnson Space Center have adapted image enhancement techniques to measure subvisual changes in the physical characteristics of human cells.

By using epithelial cells from lungs of cigarette smokers, a computer-assisted method of evaluating the degree of cell damage has been developed. This technique permits detection of minute responses to toxic fumes, particulates, or other irritants, and affords a refined method for evaluating space crew exposure to noxious substances. The procedure provides the opportunity for inflight sample collection and retrospective analysis upon return to Earth.

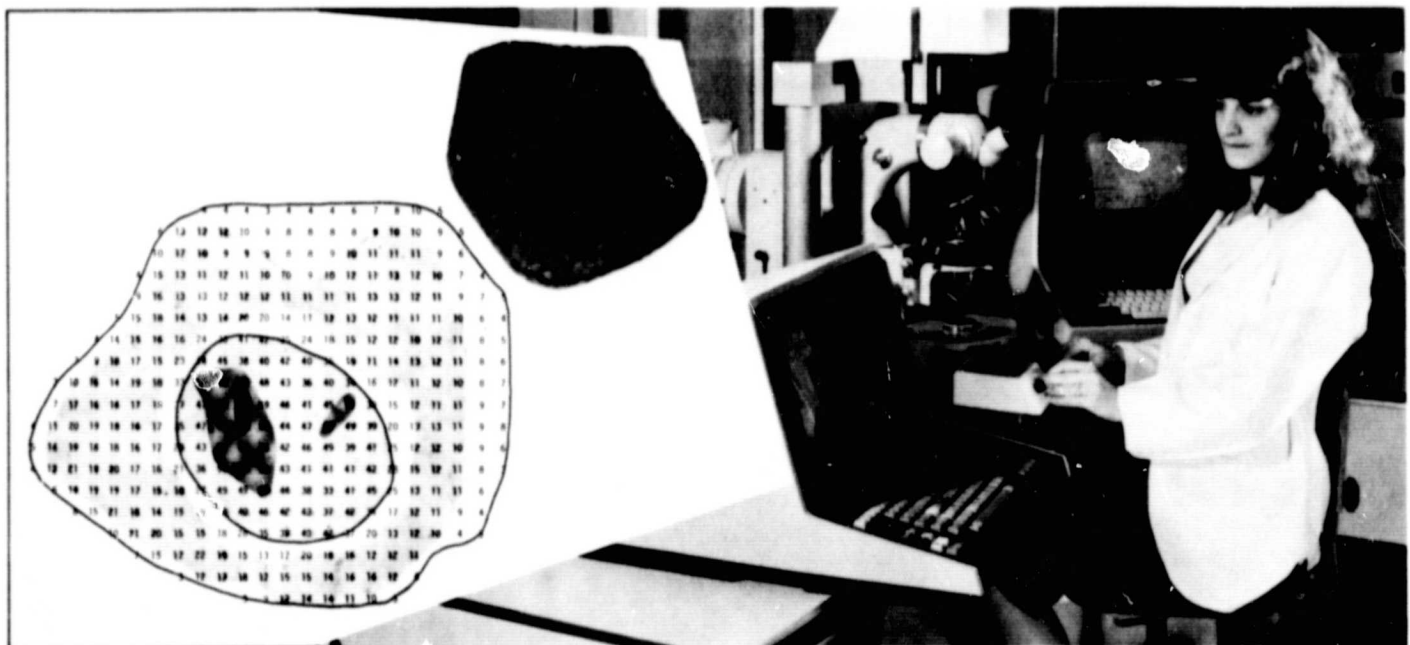
Cell Image Analysis combines light microscopy and electro-optical digitizing with computerized data process-

ing. This results in a unique quantitative characterization of biological material that can be applied to individual cells or to a cell population. The process can be divided into four phases: (1) *Preprocessing* - Specimens are collected and microscope slides are prepared and previewed. The cells to be studied are selected and their location on the slide recorded, creating a cell map. Preprocessing can be accomplished in any research or diagnostic facility having a compatible terminal and microscope. The slide and the cell map can be mailed to the Cell Image Analysis Laboratory for study. (2) *Image acquisition* - Each subject cell is then relocated on an online microscope and is displayed on a monitor where the cell image is divided into tiny squares called picture elements or pixels. Each pixel is given a discrete value resulting in digitization of the image; (3) *Image processing* - Each cell is edited (removal of extracellular debris) and the resulting, clean digitized image is stored on magnetic tape for future analysis; (4) *Image analysis* - Cell data are transferred to the master-computer where complex data analyses take place.

Cell Image Analysis employing computer-assisted image enhancement techniques, overcomes many of the limitations of standard cytological methods such as viewer subjectivity

and differences in visual perception. In this way, heretofore undetectable cellular changes may be seen and quantitated. This has opened new dimensions to cellular analysis in the areas of biomedical research, to medical diagnosis in general, and to space medicine in particular. For example, muscle mass loss following space flight has been precisely measured in rats showing a 20.4 percent loss in fast muscle fiber size and a 34.7 percent loss in the slow muscle fibers. It has been demonstrated that animals exposed to "sub-toxic" levels of the toxicant chlordane sustained chromatin alteration which could only be qualitatively verified by image analysis. Because of its unique ability to measure subtle change, image analysis provides a way to use human lymphocytes to measure radiation. Very small amounts of radiation can effect the normal blastogenic response of lymphocytes to mitogenic stimulation. Image analysis can also be used as a research tool to quantify inflight changes in cell morphology that are not detectable by standard microscopic methods. Such techniques were used following the Apollo series to help study the inflight loss of red blood cell mass. The technique was used to help study the effect of space flight on human embryonic lung cells during the Skylab mission.

Figure 1 — Cell image processing.



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Biocidal Ion Exchange

Positive control of micro-organisms in spacecraft potable water systems has been a continuing concern since the advent of manned space flight. Through the various space programs, systems of varying complexity have been developed to provide this control. These systems include both passive and active procedures and equipment. Passive measures include those measures taken before flight to initially disinfect the water system. The active measures involve the addition of disinfectants to the water as it is produced from fuel cells during the flight.

It is to the latter requirement that the development of the biocidal ion exchange system was directed. This device is being used on the Space Shuttle for potable water treatment. Different than any of the previous disinfectant additive systems, the biocidal ion exchange device does not require any crew involvement. The device incorporates an anion exchange resin that is treated with iodine as water passes through a bed (column) of the resin elemental iodine is introduced into the water. This iodine serves two purposes — it prevents the transfer of viable organisms through the bed and imparts a residual iodine level in the product water. This latter feature precludes the growth of micro-organisms downstream of the bed. Initial results from the Space Shuttle indicate that the resin device is working well.

A study is being conducted to determine the virucidal effectiveness of the device. Future studies will be conducted to determine the applicability of the device for use in spacecraft water reclamation systems involving the recycling of waste water, including urine, for potable and wash water purposes. The objective of this further study is to demonstrate the ability of the device to control organisms under characteristic operating conditions of spacecraft water reclamation systems.

Figure 1.— Microbial check valve.



Water Recovery System for Spacecraft

Long duration manned space operations, such as that of a Space Operations Center (SOC), will require vast quantities of water supplies for crew consumption, hygiene, and extravehicular activity. Transporting this water to orbit on a regular basis would be very costly. An estimated 43,000 pounds of launch weight could be saved each 3 months by recycling water for the SOC having an eight-man crew.

In consideration of the potential savings, JSC has a method under development to recover water from crew wastes, such as urine, washwater, and humidity condensate.

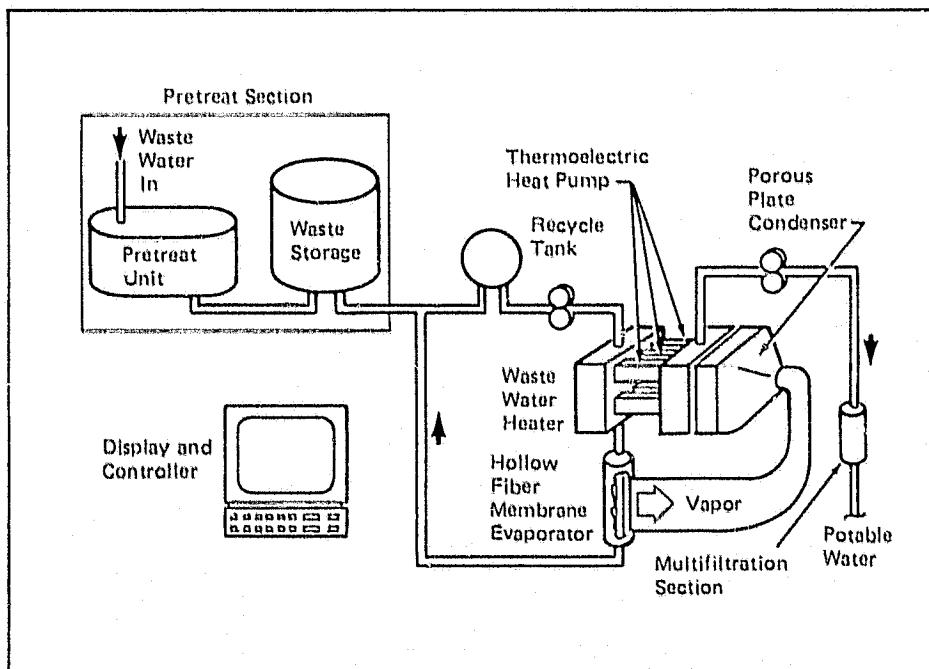
In January 1978, an effort was initiated for developing a urine water recovery process that would be an alternative to the baselined process, vapor compression distillation, which uses centrifugal force for water separation. This process, thermoelectrically integrated membrane evaporation urine water recover system (TIMES), utilizes a hollow fiber membrane evaporator and a porous plate condenser to recover potable water from urine and other sources by distillation.

Initially, the wastewater is treated with a chemical agent to prevent carryover of volatile contaminants. The wastewater is then heated to 150° F, passed through the hollow fiber membrane evaporator where the water vapor diffuses through the membrane walls to a reduced pressure steam plenum. The steam is then condensed on a porous plate condenser. Thermoelectric heat pumps are used to transfer heat from the condenser to the wastewater, thus saving the latent heat of condensation and reducing the system power penalty. The distilled product water is further treated by activated carbon, ion-exchange resins, and is disinfected by the addition of a biocide. The water, now of potable quality, is stored in tanks for use on demand.

The TIMES system has been fabricated and tested at the contractor's facility. The system weighs 300 pounds, occupies 21 cubic feet, requires 108 Whr/lb of water, and produces water at a rate of 2 lb/hr. The system is microprocessor-controlled with a multicolored graphics data display. It has undergone 500 hours of testing with urine and 250 hours of testing with washwater. Currently, certain system components are being design-optimized to improve performance and reliability. Contractor testing and improvements will continue until the scheduled delivery to JSC in early 1982. At JSC, extended tests will be performed to evaluate overall spacecraft applicability and identify design weaknesses.

Overall, the TIMES water recovery process offers promise for satisfying a critical water supply need for extended manned space operations. Additional development will improve performance and reliability and should qualify the water for spacecraft use.

Figure 1 — TIMES water recovery system.



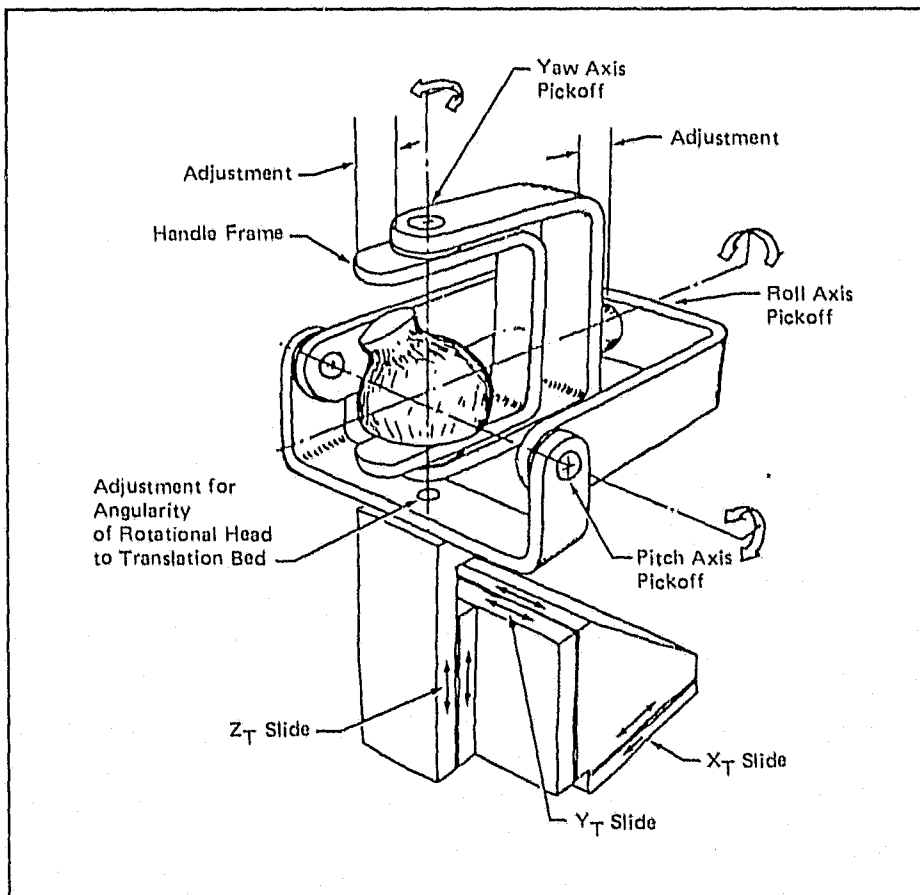
Six-Degree-of-Freedom Hand Controller

Manual control tasks of space systems in a zero-gravity environment are true six-degree-of-freedom problems. For this reason, all manned space control systems to date, whether for spacecraft, remote manipulator systems, or maneuvering units, have had two three-degree-of-freedom controllers — one for translation and one for rotation. All of these control systems have required the use of both hands to provide full control capability. Crew workload requirements make it desirable that at least one hand be available for other operations. A long proposed method for accomplishing this goal has been a single integrated six-degree-of-freedom controller. Designs for several controllers exist, but none has ever been applied to spaceflight. The intent of the research and technology study is to determine what problems have inhibited six-degree-of-freedom applications in spaceflight, attempt to solve those problems, design a controller suitable for space applications, and to deliver preliminary design drawings and specifications for a prototype controller.

The general approach for establishing the preliminary design is to search for previous six-degree-of-freedom designs, review these existing designs assessing their strengths and weaknesses, establish potential design concepts including new concepts, conduct feasibility tests, recommend a concept for design, and provide the drawings and specifications for prototype construction. The study is being conducted by CAE Electronics Ltd.

The study has progressed to the point that a concept has been developed and is undergoing feasibility testing (fig. 1). The investigation of previous designs resulted in the determination that there is currently very little work in the six-degree-of-freedom controller field. Most past work has associated with preliminary research in the Apollo program or with helicopter research. Manual controller design and evaluation is normally a minor task in vehicle handling characteristics for a particular aerospace vehicle design. Program managers are very reluctant to pioneer new territory with their particular vehicle, and pilot acceptance of new control techniques is low because of the lack of full flight simulation or actual flight evaluation. No completely documented previous research in six-degree-of-freedom manual control could be found. It is anticipated that the design developed as a result of this study could be evaluated and potentially utilized in the manned remote work station (MRWS) or as an upgrade to the Shuttle Orbiter remote manipulator system (RMS).

Figure 1.— Six degree-of-freedom controller concept test jig.



Anthropometric Measurement System

Designing work stations and living quarters for use in space requires knowledge of the physical characteristics of the people using them. Size, posture, and reach capabilities vary greatly between individuals. Finding ways to collect this information and to use it in the design process is a matter of some concern to NASA. Equipment that will collect these data in realistic situations has been developed by NASA.

Typical problems that face designers include: "Can all crewmembers reach a switch in this location?", "How much force can a crewmember exert on this handle?", "Can a person fit through this access hatch?" Traditionally, answers to these questions have been obtained by building full-scale mockups, putting people in the mockups, and trying the operations. This has been a costly, time-consuming procedure that could only be carried out after a design was nearly completed.

Figure 1.— Left-hand reach envelope for suited astronaut (photographed during data collection process).



New design procedures are being developed based on the power and flexibility of a computer-aided design system that can access descriptions of the astronaut population and make them available to design engineering from the preliminary design stage to final stages. One important step in these procedures is to collect digital data describing the region of space a person can reach (reach envelope), and how much force can be applied at points within the envelope. Many factors affect the shape and size of the reach envelope. These include the individual's size, attire (shirt sleeves or pressurized suits), and physical restraints such as seat belt, shoulder harness, foot restraints, etc. Ideally, data for each situation would be collected for the entire astronaut population.

In order to collect these data in a minimum time with maximum accuracy, an automatic system that samples and records position and force during subject motion was needed. A system, called a kinesimeter, was designed by Dr. William B. Thornton at JSC. The system consists of three video cameras that view the subject from different angles, a microprocessor to synchronize the camera scans and detect a bright spot in the video signal, and a digital recording device. A small light is attached to the point to be tracked — e.g., a fingertip — and as it moves in the field of view of the cameras, its position is digitized and recorded.

A person sweeping out a reach envelope while wearing a pressurized space suit is shown in figure 1. The elapsed-time photograph demonstrates the envelope marked by the light. The kinesimeter digitizes points from that envelope. The prototype kinesimeter uses standard video cameras, with a scene-processing time of 1/60 of a second, and can track, at most, two lights. A high-speed kinesimeter, capable of tracking up to 30 lights at a total data rate of 10,000 points per second, is nearing completion. When this system is available, it will be possible to collect information on arm and leg movement patterns, for example, by attaching a number of lights to the subject's arm and tracking the position of wrist, elbow, and shoulder as the person performs typical space tasks.

Simply collecting these numbers would be of little benefit if they could not easily be used in design and evaluation. However, the digital format of the data enables graphic display by a computer-aided design (CAD) system in conjunction with work stations and proposed tasks. In many ways, this is the functional equivalent of putting a crewmember in the work area while it is still on the drawing board. Data collected by the kinesimeter have been used for evaluating reach capabilities for assessing the feasibility of proposed extravehicular activities.

Microprocessor Based Physiologic Instrumentation

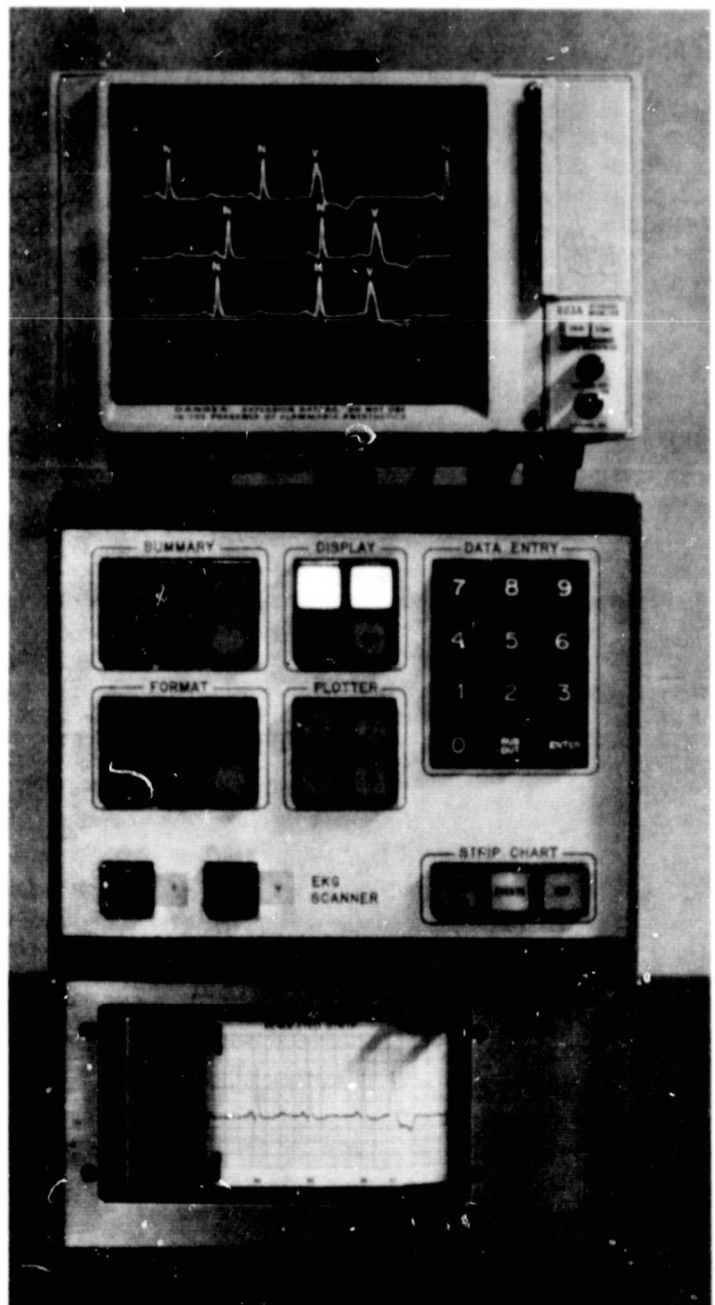
Through the years, NASA has been in the forefront in the need for and development of remote and automated biological monitoring systems.

A JSC contractor developed a bedside arrhythmia monitor. This instrument (fig. 1) is capable of receiving electrocardiographic input from a human subject and, through the use of micro-processor algorithms, categorizing each beat as normal or abnormal. If the heartbeat is abnormal, the unit then decides whether a premature beat is supraventricular or ventricular in origin and quantifies it in respect to coupling interval, frequency, or repetitive patterns. Bradyarrhythmias and tachyarrhythmias are treated with their own formats. Data can be displayed as hourly summaries or as line or bar graphs.

In the hospital setting, this technology is being utilized to replace the traditional Holter monitoring, with the advantage of immediate recall of collected data. The NASA units will be placed on the Mission Control Console at JSC for real-time monitoring of the astronauts during the second and subsequent Space Shuttle missions.

Although the arrhythmia monitor does not eliminate the need for human overreading, precise quantitation and assurance that data are not lost are major advances of the system.

Figure 1.-- A bedside arrhythmia monitor.



Regenerable Carbon Dioxide (CO₂) Removal for Portable Life Support Systems

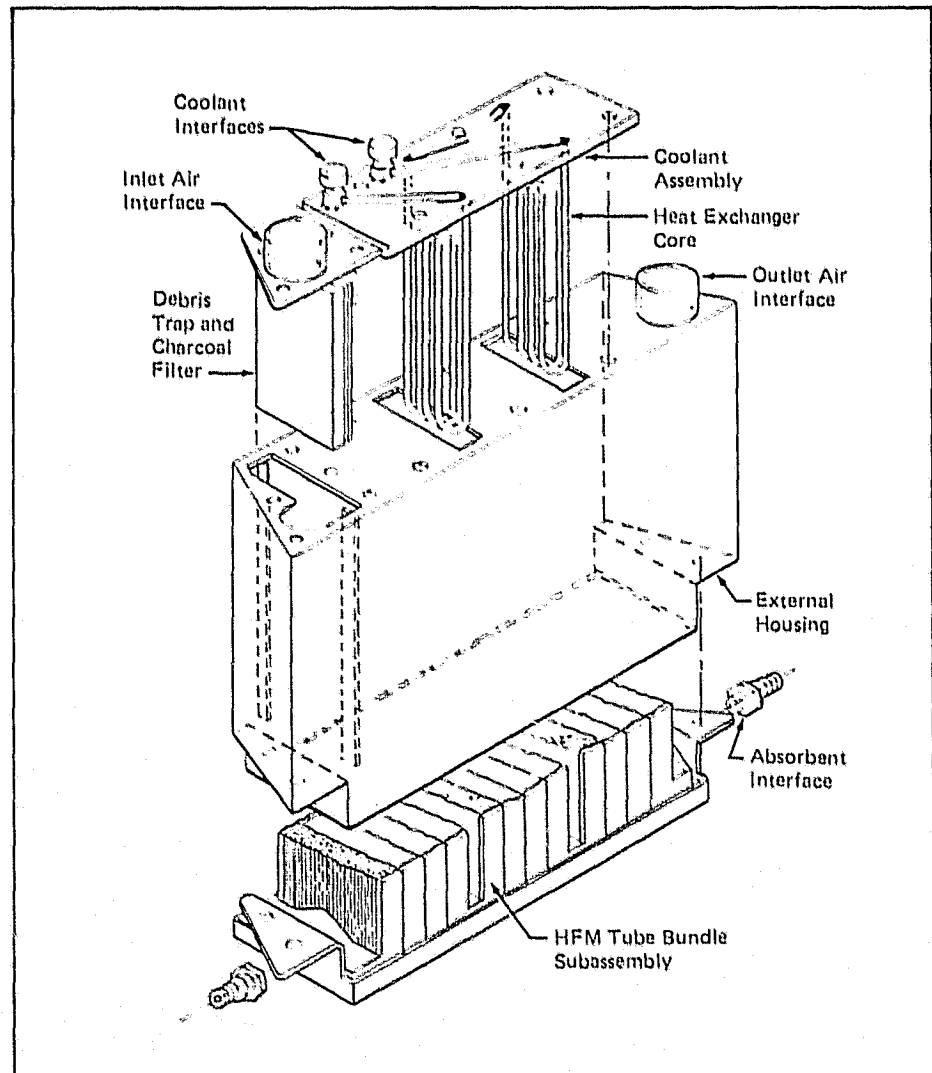
Carbon dioxide (CO₂) control on the portable life support system for extravehicular activity (EVA) is presently accomplished by the use of expendable lithium hydroxide cartridges. This approach, while adequate for the few EVA's anticipated for the early STS missions, would represent a sizable weight, volume, and logistics burden on future planned programs where a significant number of EVA sorties may be needed to deploy and assemble large systems in space.

A regenerable concept that will provide the CO₂ control during EVA at a fraction of the weight and volume penalty has been under development for several years (fig. 1). The concept basically involves absorbing the metabolic CO₂ in an absorber cartridge similar to the present lithium hydrogen cartridge and then

regenerating the spent absorbent electrochemically onboard the spacecraft. In the absorber cartridge, an aqueous hydroxide electrolyte is retained in hollow fiber membrane tube bundles. As the CO₂-laden air is passed over the hollow fiber membrane tubes, the CO₂ is absorbed by the electrolyte, reacting with the hydroxyl ions to form carbonate ions. At the conclusion of an EVA, the expended electrolyte is transferred out of the hollow fiber membrane tubes into a processor module where it is electrochemically regenerated. The products of the regeneration process are a "refreshed electrolyte" absorber for EVA use and CO₂ which may be further processed by the spacecraft system for reclamation of the O₂.

To date, it has been demonstrated that hollow fiber membrane tubes are suitable for retaining the aqueous electrolyte and for allowing adequate CO₂ diffusion into the electrolyte. Also, the regeneration process has been demonstrated successfully at the single-cell level. The next phase in the development will involve fabrication of a full size absorber cartridge and a multicell regenerator module.

Figure 1.— Electrochemical regenerable carbon dioxide absorber assembly.



Space and Terrestrial Applications

Office of Space and Terrestrial Applications

Summary

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AgRISTARS Program

The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) is a continuing 6-year program of research, development, evaluation, and application of aerospace remote sensing for agricultural resources. It began in fiscal year 1980 and is a cooperative effort of the U.S. Department of Agriculture (USDA), NASA, the U.S. Department of Commerce, the U.S. Department of Interior, and the Agency for International Development.

The goal of the AgRISTARS Program is to determine the usefulness, cost, and extent to which aerospace remote-sensing data can be integrated into existing or future USDA systems to improve the objectivity, reliability, timeliness, and adequacy of information required to carry out USDA missions. The overall approach is comprised of a balanced program of remote-sensing research, development, and testing that addresses domestic resource management as well as commodity production information needs.

The program specifically addresses the seven information requirements identified in the USDA Secretary's Initiative.¹

1. Early warning of change affecting production and quality of commodities and renewable resources
2. Commodity production forecasts
3. Land use classification and measurement
4. Renewable resources inventory and assessment
5. Land productivity estimates
6. Conservation practices assessment

¹Joint Program of Research and Development of Uses of Aerospace Technology for Agricultural Programs, dated February 1978.

7. Pollution detection and impact evaluation.

While all seven are important to the USDA, the first two—early warning and commodity production forecasting—have been given emphasis because of the immediate need for better and more timely information on crop conditions and expected production.

The technical program is structured into eight major projects, as follows.

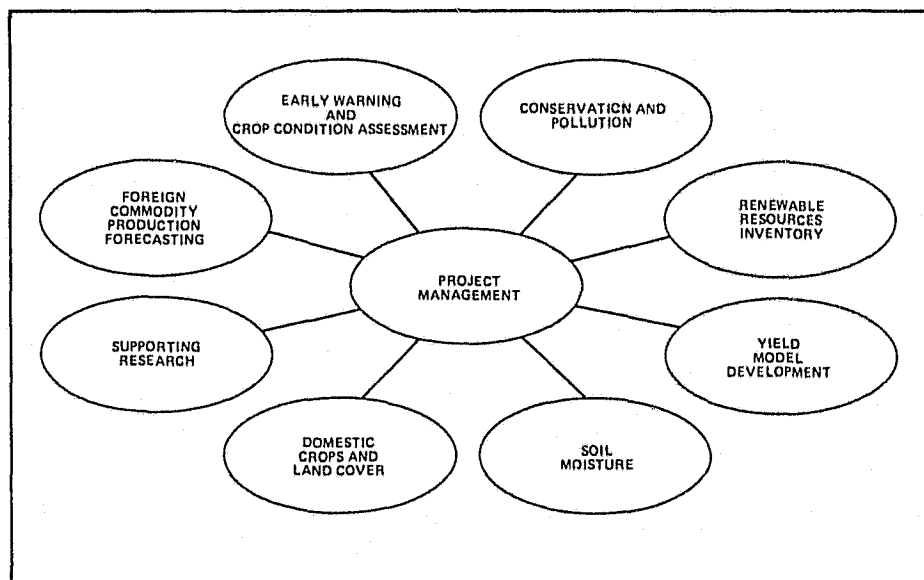
1. Early Warning/Crop Condition Assessment
2. Foreign Commodity Production Forecasting
3. Yield Model Development
4. Supporting Research
5. Soil Moisture
6. Domestic Crops and Land Cover
7. Renewable Resources Inventory
8. Conservation and Pollution

These elements (fig. 1) are interrelated through research, exploratory experiments, pilot experiments, USDA user evaluations, and large-scale application tests.

The Early Warning/Crop Condition Assessment effort is focused on providing the technology required for worldwide identification of environmental conditions that affect agricultural production and surveillance of resulting crop conditions through remote sensing and environmental monitoring. A wide variety of tasks must be performed to provide that technology: basic research on crop response (both physiologically and spectrally) to the environment; field observations to support that research; extensions to or modification of the results of past research efforts and ongoing efforts both in and out of AgRISTARS; testing; and modeling the results into a system that can operate in a timely manner on available data and can be easily adapted to specific operational needs.

Early Warning/Crop Condition Assessment is colocated at the Johnson Space Center with the U.S. Department of Agriculture Foreign Agricultural Service, Foreign Crop Condition Assessment Division, and

Figure 1.— Component projects of AgRISTARS.



responds to the research needs defined by that operational group. Much of the research is performed by researchers at Agricultural Research Service sites or by university groups. The molding of the research findings into the quasi-operational procedures is performed by the Early Warning/Crop Condition Assessment group in Houston on the same computer system used by the Foreign Agricultural Service in making their operational estimates of foreign production.

The Foreign Commodity Production Forecasting activity addresses crops and region combinations in the U.S. and foreign countries (U.S.S.R., Argentina, Brazil, Canada, and Australia) for small grains, corn, and soybeans. This project will develop and test affordable procedures for using aerospace remote-sensing technology to provide more objective, timely, and reliable crop production forecasts several times during the growing season and improved preharvest estimates for the crops and regions of interest. The Foreign Commodity Production Forecasting activity builds upon the existing remote-sensing technology base and extends this technology to additional crops and regions.

Forest Resource Information System

The prime goal of this application pilot test was to demonstrate and transfer satellite remote sensing technology to a major forest product industry user. A cooperative agreement was established with the Southern Timberlands Division of the St. Regis Paper Company, and they also shared in the management and costs of the project. NASA shared in the management and provided the cost for the Laboratory for Applications of Remote Sensing (LARS); Purdue University was responsible for the technical demonstration of using Landsat multispectral data, the training of the St. Regis personnel, and assisting in the technical design of the system. When St. Regis made a decision to implement the system, NASA and LARS provided for the transfer of Landsat processing and classification software to their computer system, and this became a major component of the Forest Resource Information System.

The adoption of this technology by St. Regis into an operational environment was economically feasible in terms of managing data and forest-related resources and providing for new efficiencies in operational tasks with this advanced automated system. A joint NASA/St. Regis/Purdue University Conference on Space Technology and Industrial Forest Management was held in Jacksonville, Florida, in May 1981, to demonstrate the successful implementation of the system and provide the wood product industries users an opportunity to evaluate the uses of satellite technology for managing forest resources.

Wildland Vegetation Resource Inventory

The Wildland Vegetation Resource Inventory Application Pilot Test (APT) conducted jointly by JSC and the Bureau of Land Management of the Department of the Interior was completed in September 1981 with receipt of final project documentation. The purpose of the APT was to test and implement an interactive system based on remote sensing technology to assist in the inventory of public lands under the jurisdiction of Bureau of Land Management. The project was planned as a three-phase effort in Alaska, Arizona, and Idaho beginning in May 1977. During the tenure of the project, the Bureau of Land Measurement purchased a mini-computer system and established a Branch of Remote Sensing at the Denver Service Center. The BLM demonstrated their in-house capability by independently accomplishing the Phase III Idaho test. As a direct result of the APT, the Bureau of Land Measurement has operational projects using remote sensing in four western states with additional projects on the drawing board for fiscal year 1982 and beyond.

Texas Application System Verification and Transfer

The JSC is participating with the State of Texas in a joint Application System Verification and Transfer Project to develop, evaluate, and transfer techniques for applying Landsat and other data to the needs of Texas natural resources management agencies. The major objectives of the project are (1)

to update and integrate state-of-the-art remote-sensing technology with other information sources available to the State to form a functional Texas Natural Resources Inventory and Monitoring System, and (2) to test and evaluate the utility and cost-effectiveness of natural resource information derived from Landsat data and other sources when applied in a total system context to selected State agency management activities. The Texas Applications Project began in June 1978 and will continue for 4 years.

The remote-sensing component, including technical assistance in techniques development of the system, is NASA's major responsibility. A prototype of the system is now operational on Texas facilities. The system is being tested and evaluated in support of application categories in the areas of coastal zone management, forestry, water resources, mineral resources, and wildlife management.

Office of Space and Terrestrial Applications

Significant Tasks

85 Forest Resource Information System

Funded by: Resource Observation, Applied Research,
and Data Analysis (UPN-677)

Project Manager: R. E. Joosten/SH2

Task Performed by: Purdue University Laboratory for
Applications of Remote Sensing
Contract NAS 9-15325

86 AgRISTARS: Scene Radiation Research

Funded by: Resource Observation (UPN-691)

Project Manager: W. E. Rice/SA

Task Performed by: NASA, U. S. Department of Agriculture,
and U. S. Department of Commerce

88 AgRISTARS: Pattern Recognition Research

Funded by: Resource Observation (UPN-691)

Project Manager: W. E. Rice/SA

Task Performed by: NASA, U. S. Department of Agriculture,
and U. S. Department of Commerce

90 AgRISTARS: Early Warning/Crop Condition Assessment Project

Funded by: Resource Observation (UPN-691)

Project Manager: W. E. Rice/SA

Task Performed by: NASA, U. S. Department of Agriculture,
and U. S. Department of Commerce

92 AgRISTARS: Foreign Commodity Production Forecasting Project

Funded by: Resource Observation (UPN-691)

Project Manager: W. E. Rice/SA

Task Performed by: NASA, U. S. Department of Agriculture,
and U. S. Department of Commerce

94 Wildland Vegetation Resource Inventory

Funded by: Resource Observation, Applied Research,
and Data Analysis (UPN-677)

Project Manager: K. J. Hancock/SH2

Task Performed by: ESL Corporation
Contract NAS 9-15740

95 Texas Natural Resources Inventory and Monitoring System

Funded by: Applications Systems Verification Test (UPN-658)

Project Manager: L. F. Childs/SK

Task Performed by: Lyndon B. Johnson Space Center
Department of Water Resources
Contract T-3499H

96 Extended Scene Radar Calibration

Funded by: Resource Observation (UPN-677)

Technical Monitor: R. G. Fenner/ED6

Task Performed by: Lyndon B. Johnson Space Center

97 SIR-A Antenna Integration into Orbiter

Funded by: Resource Observation (UPN-666)

Technical Monitor: H. A. Nitchske/ED6

Task Performed by: Lyndon B. Johnson Space Center
Ball Brothers Aerospace Corporation
Contract NAS 9-15512

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Forest Resource Information System

With the completion of the St. Regis Paper Company/Purdue University/NASA Application Pilot Test Project in December 1980, St. Regis has implemented a Forest Resource Information System (FRIS) in an operational environment (fig. 1). The goal of FRIS was to demonstrate the use of satellite data for its contribution to a forest information system, both technically and economically, and support operational functions by the user.

This was accomplished by developing specific quantifiable forest resource information from Landsat multispectral scanner data and correlating with forest inventory data on specific test areas throughout the southeastern United States (fig. 2). (See FY-1980 Research and Technology Annual Report.)

The specific software developed by the Laboratory for Applications of Remote Sensing (LARS), Purdue University, for processing Landsat-type data was transferred to St. Regis and is a major component of the total system. As a result of the various project activities, several significant statements can be made.

1. Landsat satellite data have made important contributions in assessing and monitoring natural resources.

2. Digital information from space can help in carrying out a variety of functions for forest management operations.

3. Satellite data merged into an information system offer a more responsive means to meet the increasing information needs in managing forest-related resources.

As a result of the successful completion of the project and the actual implementation of an information data base system, St. Regis, LARS, and NASA hosted a "Conference on Space Technology and Industrial Forest Management." The conference was held in Jacksonville, Florida, on May 7-8, 1981, and provided a unique opportunity to demonstrate the value of the system, why and how it was imple-

mented, and its operational flexibility. Presentations were made by St. Regis, LARS, and NASA, and further augmented by speakers from private industry, universities, and government involved in various aspects of remote sensing, data acquisition, and technology transfer. A total of 130 individuals attended the conference representing 21 forest product companies, four Federal agencies, three state governments, one foreign country, nine colleges and universities, and six other private firms. The highlight was the opportunity to observe operation of the FRIS Center that was established by St. Regis early in 1980.

While the completion of the joint APT project was successful in its demonstration and technology transfer, St. Regis operational activities utilizing the system have just started. It is estimated that digitizing 2.3 million acres of timberland they own or control throughout the six southeastern states as input into the automated data base will consume 2 to 3 years of intensive activity. Upon completion, St. Regis will have an operational system to merge various types of information that will be responsive to critical operational activities and provide greater efficiencies in managing their valuable resources for the future.

Figure 1.— The four phases of the St. Regis Project

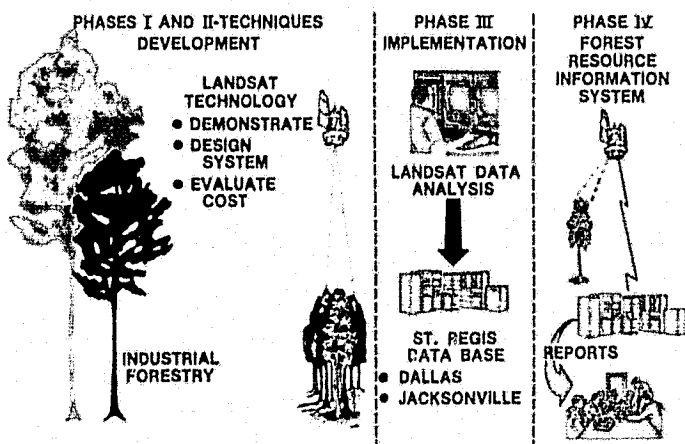
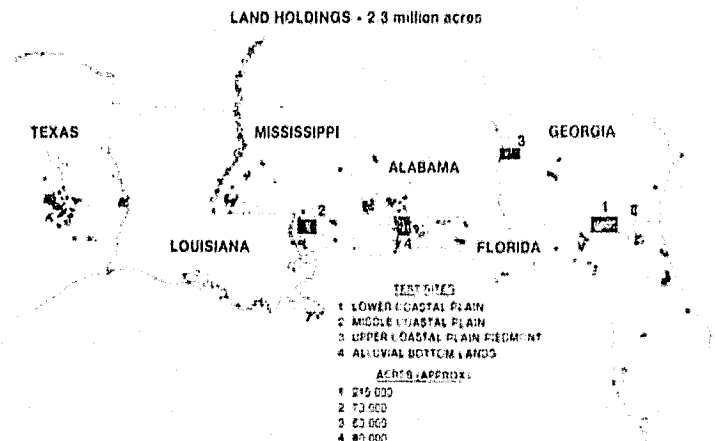


Figure 2.— Land holdings of the Southern Timberland Division of the St. Regis Paper Company.



AgRISTARS: Scene Radiation Research

Scene Radiation Research investigates crop stage development models; the use of spectral/meteorological variables to monitor crop condition; and performs feature selection/extraction analysis in support of crop identification and condition monitoring. Research is being performed to develop a technology for modeling and simulating Earth scenes including atmospheric and sensor effects.

A major goal of the Supporting Research Project is to advance the state-of-the-art technology in agronomic remote sensing to quantitative rather than qualitative level. A significant accomplishment in Scene Radiation Research in 1981 was the development of a wheat stress index model by AgRISTARS researchers that predicts the daily crop moisture stress of wheat and its phenological development. The model was developed by using improved thermal and photothermal responses and adding a moisture stress index variable to account for the effect of moisture on phenology. The model also has the capability to accept data as an input for planting date, leaf area index, and soil moisture.

The wheat stress index model has two main components: a biological clock that generates the phenological progression of the crop and the daily

crop moisture stress index (fig. 1). Crop phenology is modeled from temperature and photoperiod response of the crop from emergence to physiological maturity. The influence of the crop-moisture-deficit condition on phenological development is an important input parameter in the model. The model simulates the slowing down and hastening effects on development due to moisture stress. The crop moisture stress index is derived from simulation of water relations in the soil-plant-atmosphere continuum. The stress index reflects the moisture deficit condition of the crop relative to the available soil moisture, the evaporative demand of the environment, and the crop water requirements at a given stage of development.

Evaluation of the wheat stress index model, including a comparison with the Robertson Biometeorological Time Scale model over independent data acquired in the 1980 crop year from the Northern Great Plains, has been completed. Both models were initiated by using the ground-observed planting date for each field and the same form of predicating emergence dates. Each model was found to be well correlated with the ground emergence date for each of the 204 fields with no indication of bias. Both models were well correlated with the ground-observed estimates of growth stage from tillering through maturity.

Overall, the wheat stress model

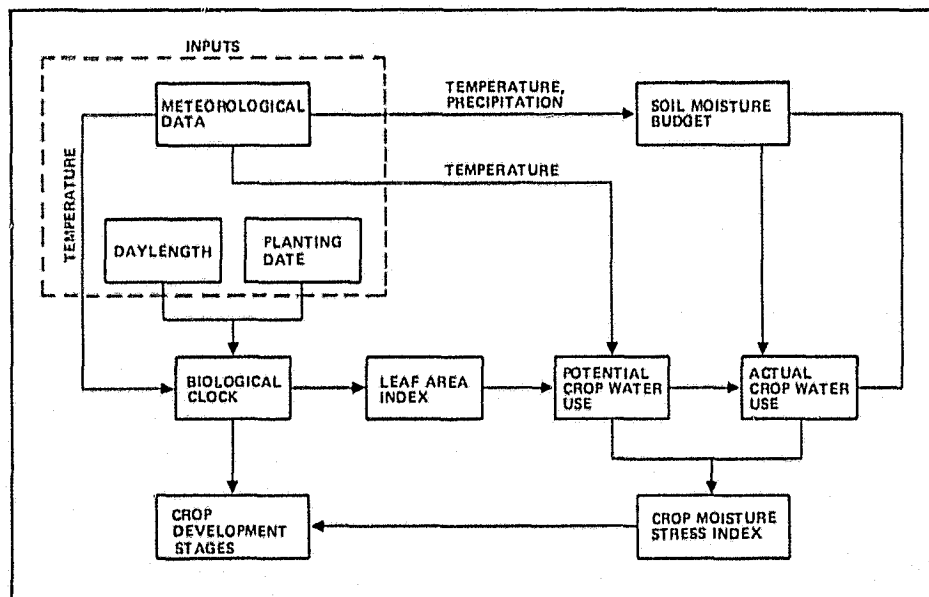
provided significant improvement over the Robertson model based on a field-by-field growth-stage error analysis. Eighty percent of the wheat stress model estimates were within .5 stage of the ground observed estimates, while only 68 percent of the Robertson model estimates were within .5 stage. The improvement occurred primarily in the heading and seed development stages for spring wheat.

High accuracy for these stages is especially important for crop identification using remotely-sensed data and for yield estimation, since stress during these stages can reduce yield by as much as 50 percent. The model has been requested by USDA for evaluation for use in their operational system. Further improvements to the wheat stress model are anticipated by incorporating spectral data to estimate planting date, leaf area index, and soil moisture.

Simulation of spacecraft sensors (another Scene Radiation Research effort) is important in projecting the performance of the thematic mapper prior to launch, and it is also important in evaluating the sensitivity of information extraction algorithms (e.g., crop identification, crop condition, and crop stage) to the varying conditions under which the data are taken. Using the simulated data, selected variables can be held constant, while the variable of interest is changed, and the sensitivity of the algorithm evaluated. For example, the impact of impure pixels on classification can be examined as a function of registration error. Similarly, the effect of acquisition loss on accuracy can be examined.

Simulation of spacecraft imagery over agricultural areas requires the field structure, sensor response, crop reflectance distribution, atmospheric characteristics, and cropping practices to be modeled. Two approaches have been used for generation of the simulated thematic mapper data. In the first approach, an aircraft scanner (NS-001), which is similar to the thematic mapper, was used to collect data over a corn and soybean area in Webster County, Iowa. These data were then scan-angle corrected, calibrated, rectified, and resampled so that the data closely approximate the thematic mapper data (fig. 2). This approach has the advantage of having true agricultural field boundaries and

Figure 1.—Simplified diagram of the flow of the wheat stress indicator model.



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true variability within and between fields, but it has the disadvantages that the aircraft data must be corrected for scan angle, etc., and that numerous aircraft missions must be flown to simulate a crop year. The second approach involves modeling and simulation based on field spectrometer data, converting it to the thematic mapper bands, calibrating the data, and painting a raster scan of the data at thematic mapper and multispectral scanner resolution using realistic field boundaries from aerial photography. However, to use this approach, models are required to develop realistic estimates of within and between field variability. Once such models are available one can control the characteristics of the scene, such as the spectral distribution of each crop, the spectral distribution of the boundary (or mixed) pixels, and the field size distribution. Acquisition dates can be simulated to reduce the large number of aircraft flights by incorporating a temporal model of the crop reflectance. Figures 3 and 4 show images of both thematic mapper resolution and multispectral scanner resolution for a small grains/corn area in Kingsbury County, South Dakota, generated by using this technique. The improved resolution of the thematic mapper shows much improved field boundaries especially for the strip fallow fields in the upper right of the image. Research has shown that 80 percent of the crop pixels will be pure for thematic mapper (i.e., only one crop per pixel), whereas with multispectral scanner, 40 percent of the crop pixels will be pure.

In the near future, these simulation tools will be used to investigate the effect of the boundary pixels on classification performance, the temporal sampling effect on classification performance, and the improvements of thematic mapper over the multispectral scanner in terms of classification performance.

Research is also underway to merge these two approaches to simulation with a third; which uses a crop reflectance model (Suits) and a crop development model or growth model (Ritchie). This will allow even more flexibility in performing sensitivity analyses of crop scenes since the crop profile will be able to be generated without assuming the ap-

plicability of an empirically derived temporal model. Sensitivity studies of reflectance to leaf area index, biomass, water stress, et cetera, will then be feasible with only minimal aircraft data and field spectrometer data.



Figure 2.— Simulated thematic mapper data.

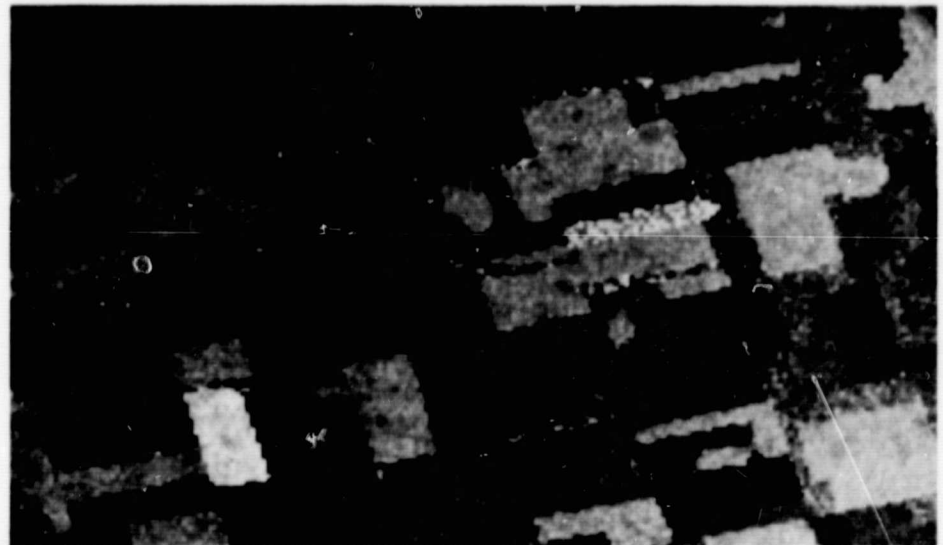


Figure 3.— Simulated thematic mapper (TM) scene of spring wheat segment. Blue, green, and red = channels TM-2, TM-3, and TM-4.

Figure 4.— Simulated thematic mapper (TM) scene of spring wheat segment with multispectral scanner resolution. Blue, green, and red = channels TM-2, TM-3, and TM-4.



AgRISTARS: Pattern Recognition Research

Pattern Recognition Research investigates automated information extraction approaches for crop identification, crop growth stage estimation, and crop condition monitoring. It is designed to develop accurate and efficient procedures for crop-area estimation being investigated at both single segment (5 by 6 nautical miles) and at the large geographical region (multisegment) level. Accurate identification of key crop development stages and the assessment of the condition of the crop are important elements in the advanced-crop-acreage-estimation research program. The pattern recognition research program is integrated with scene radiation research and receives a number of important inputs from that program.

In LACIE, registered multirate multispectral scanner system (MSS) data were provided by the Goddard Space Flight Center LACIE processor. This system provided registration at the 1974 state-of-the-art technology. AgRISTARS is now using data processed at Goddard Space Flight Center and further refined by the JSC registration processor. Preliminary estimation of the registration accuracy with this combined system is at or

below 0.5 pixels. Further improvements toward the goal of 0.2-pixel accuracy are in work.

Many crops appear spectrally similar in Landsat MSS data at a given point in time; separation of these crops are only possible by use of multirate sequences of MSS imagery, which allow individual crops to be recognized on the basis of their temporal spectral development. Multirate sequence analysis does not produce 100 percent accuracy in crop recognition because of visibility of crop temporal spectral development patterns (signatures) because of such factors as planting date, variety, and weather. The approach to this problem has been predicated on the following judgments:

1. The requirements to assess the crop identity at a sufficiently large number of locations to make an accurate estimate of crop proportions cannot possibly be done economically unless it is automated.

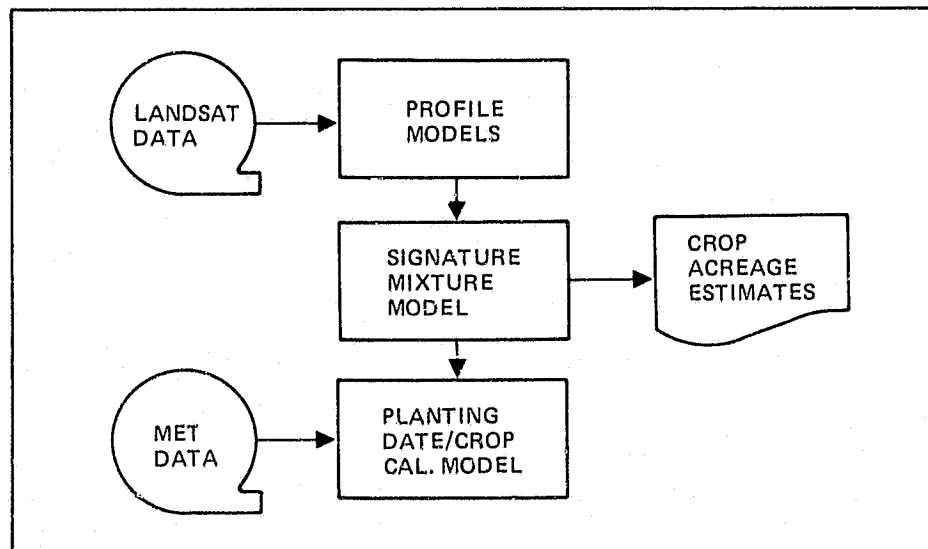
2. The current lack of quantitative understanding of how crop signatures are affected by external factors requires the use of a human analyst to adjust the parameters of the automated processing system to the local conditions.

In practice, the analyst has to

manually identify ("label") training samples from the Landsat image to be machine processed. An approach called APEP (Advanced Proportion Estimation Procedure) for estimating a crop acreage not requiring manually identified-training samples is being studied. The estimates for this approach can be unbiased, which is a consequence of abandoning previously used classification approaches in favor of a "direct" method for estimating crop acreage.

The major functional elements of APEP are shown in figure 1. By using models of crop growth, called profile models, successive Landsat acquisitions of data over time are transformed into a sequence of growth-variable values. The primary function of these transformations is to remove extraneous effects of the data that are irrelevant for crop identification. A statistical model, called a mixture model, is then used to estimate the proportions of the crops of interest in the Landsat scene. To complete the process, each proportion estimate must be given a crop name which is referred to as a labeling function. Labeling is achieved by associating a predicted growth curve for a given crop, as derived from meteorological data, with one of the growth curves estimated from the mixture model.

Figure 1.— Advanced proportion estimation procedure (APEP).



In the 1980 report, the Crop Spectral Temporal Profile (fig 2) was reported. The profile is a mathematical representation of the Landsat multitemporal data which is the key to any area estimation procedure. This representation of the MSS data permits an extraction of agronomically meaningful features of the crop such as planting date, growing-season length, the rate of greenup, and the senescence rate. An area estimation procedure based on these agronomic variables has been developed for the separation of corn, soybean, and others. It has been implemented and tested on data acquired in 1978 and 1979. Results of the verification tests show a nearly-unbiased estimate of the three crop categories.

Figure 3 shows a histogram of the rate of greenup calculated from Landsat MSS data acquired over an AgRISTARS segment, 0882, in Iowa in 1978. This shows clearly the separation that is possible between the three categories. Using various other variables calculated from the Landsat, the analyst objectively marks 15 to 20 pixels per class in a very short time (less than 1 hour). A linear classifier is trained on these pixels, and decision planes for reporting the crop categories are determined. Each pixel is then classified by using these planes. This

technique shows promise of complete automation and indicates that area estimation is possible about 60 days after corn planting.

In summary, the 1981 effort in Sup-

porting Research has resulted in substantial technical progress and has placed the Supporting Research in a good position to initiate the work to be performed in subsequent years.

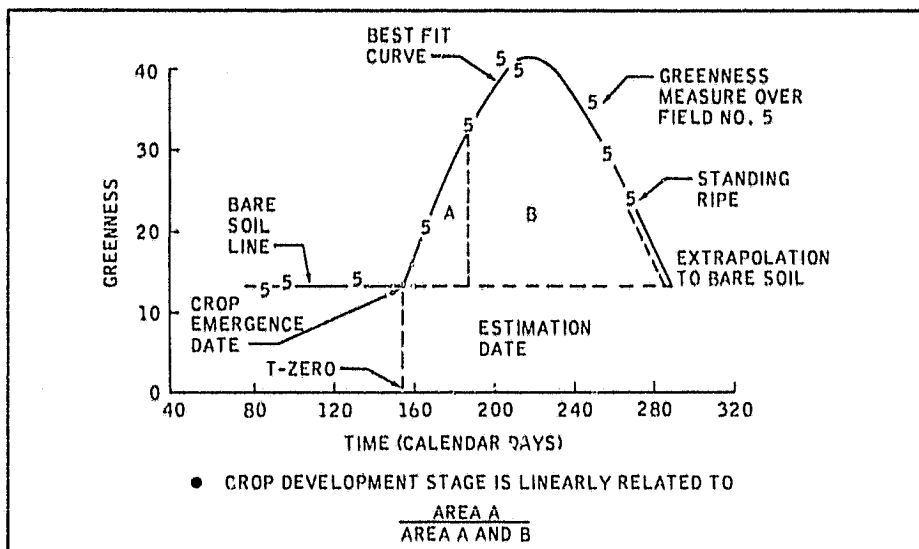
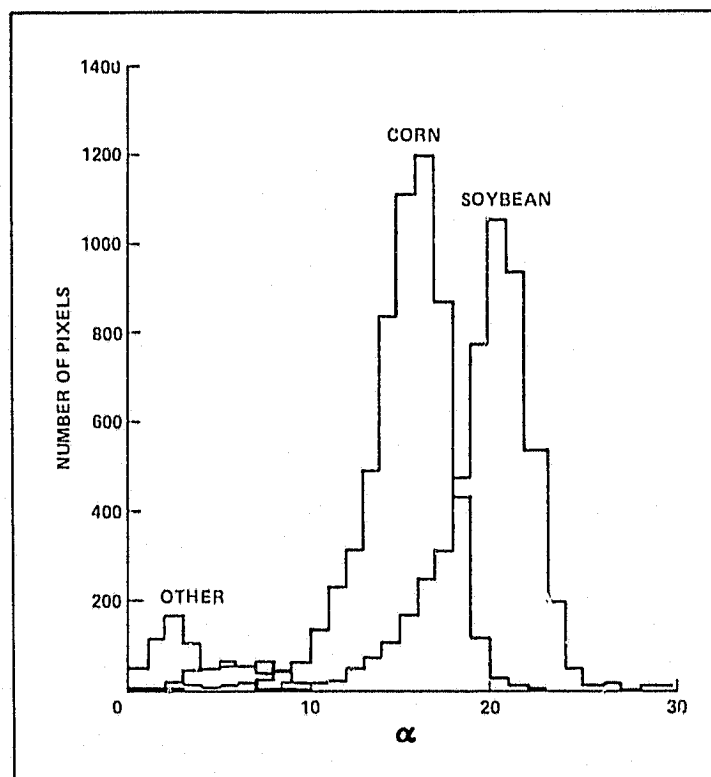


Figure 2.— Spectral profile crop development stage estimation.

Figure 3.— Rate of crop greenup.



AgRISTARS Early Warning/Crop Condition Assessment Project

The Early Warning/Crop Condition Assessment Project of AgRISTARS is dedicated to development of a technology that will permit a timely response to factors that affect the quality and production of economically important crops. This involves the ability to identify the growing factors that influence crop conditions and to determine the amount and condition of the crops involved. Resources from the Agricultural Research Service (ARS) and Statistical Reporting Service (SRS) of the U.S. Department of Agriculture (USDA), NASA, and National Environmental Satellite Service (NESS) and Environmental Data and Information Service (EDIS) of the National Oceanic and Atmospheric Administration (NOAA) are integrated to provide a comprehensive and efficient approach to this multifaceted problem. Project personnel are colocated with a using unit of USDA, the Foreign Agricultural Service (FAS) — Foreign Crop Condition Assessment Division (FCCAD), to better insure relevance of the resulting products.

Products provided by Early Warning/Crop Condition Assessment represent improvements over existing technology (improved accuracy, more timely performance, and extension to other areas and crops). Initial emphasis was placed upon the upgrading of procedures in use by FCCAD. Procedures to objectively assess crop losses due to hot dry winds and poor harvest conditions, both major causes of reduction in U.S.S.R. production of small grains, were needed (fig. 1). Alarm models that automatically track environmental conditions and include soil moisture budgets and crop calendars were provided to permit the analyst to concentrate on the areas needing more attention. These alarm models have been developed for small grains, corn, and sorghum, and they are being developed for soybeans, cotton, sunflowers, and sugar beets. Stress models that provide a relative measure of severity of stress conditions are to follow.

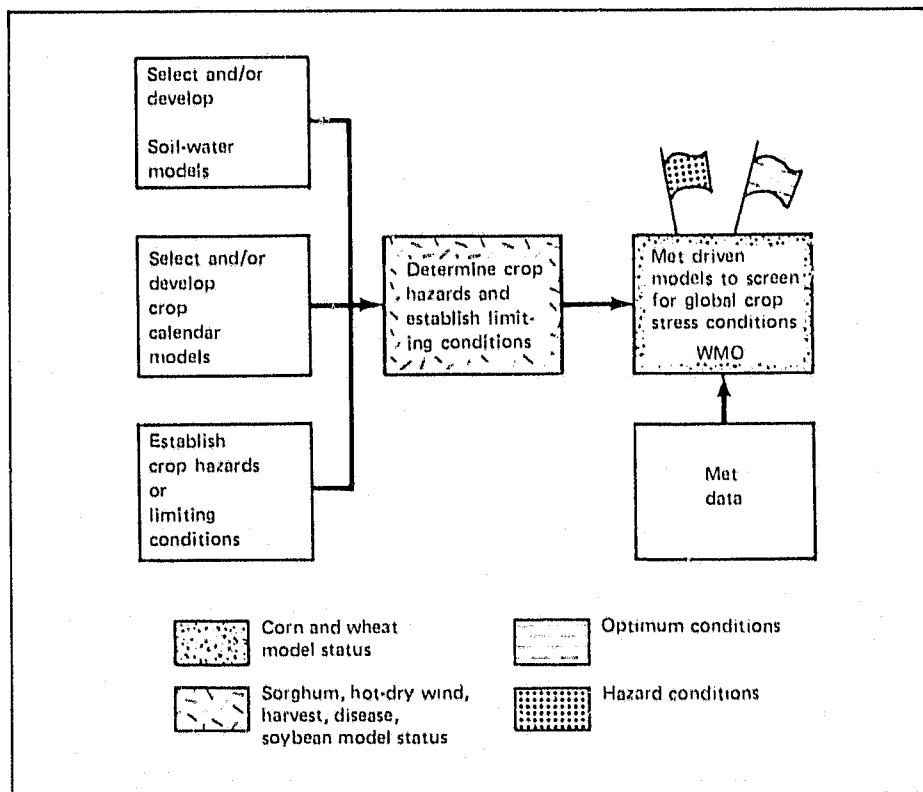
Parallel to this development and improvement in this technology driven by environmental data, a major effort

has been made to provide means to exploit remotely acquired data. Techniques developed in the course of LACIE and by other AgRISTARS projects are not directly applicable to many of the Early Warning Crop Condition Assessment applications, but much of the past field research effort and vegetative index research is pertinent and provides a firm foundation for spectral data use (fig. 2). Several tasks in progress rely heavily on satellite-based observations. Flood damage assessment, range condition assessment, and native vegetation as a crop stress indicator are specific examples of application of spectral data. Because many of the requirements placed on the Early Warning/Crop Condition Assessment project by the user are of a broad-scale nature, emphasis was placed upon regional conditions instead of specific point conditions. This project has served as a pioneer in the application of environmental satellite data (NOAA-6 and -7 and GOES) as an agricultural surveillance tool (fig. 3). On a broad scale, estimates of vegetative indices based on data from these satellites can be used to bridge the spatial and temporal gaps in Landsat data. These

estimates can be made daily (except for clouds), with a pixel size of 4 kilometers on a side routinely available worldwide, 1 kilometer on a side available on prior request. Tracking of the progress of the seasons and surveillance of agricultural vigor are obvious applications that can be performed by using only environmental satellite data after a reference base has been established.

Some difficult problems remain to be solved before full use can be made of satellite data. While there is no question that crop stress of certain types can be identified from satellite data, noise originating from different illumination and viewing geometries, atmospheric attenuation and cropping practices can confuse the interpreter unless procedures to account for these are provided. These problems are being addressed, and objective repeatable estimates of vegetative indices are expected to become available during the coming year. It is clear that the most efficient procedures developed during the Early Warning/Crop Condition Assessment effort will be based on a mixture of environmental and satellite data.

Figure 1.—EW/CCA approach to alarm model development.



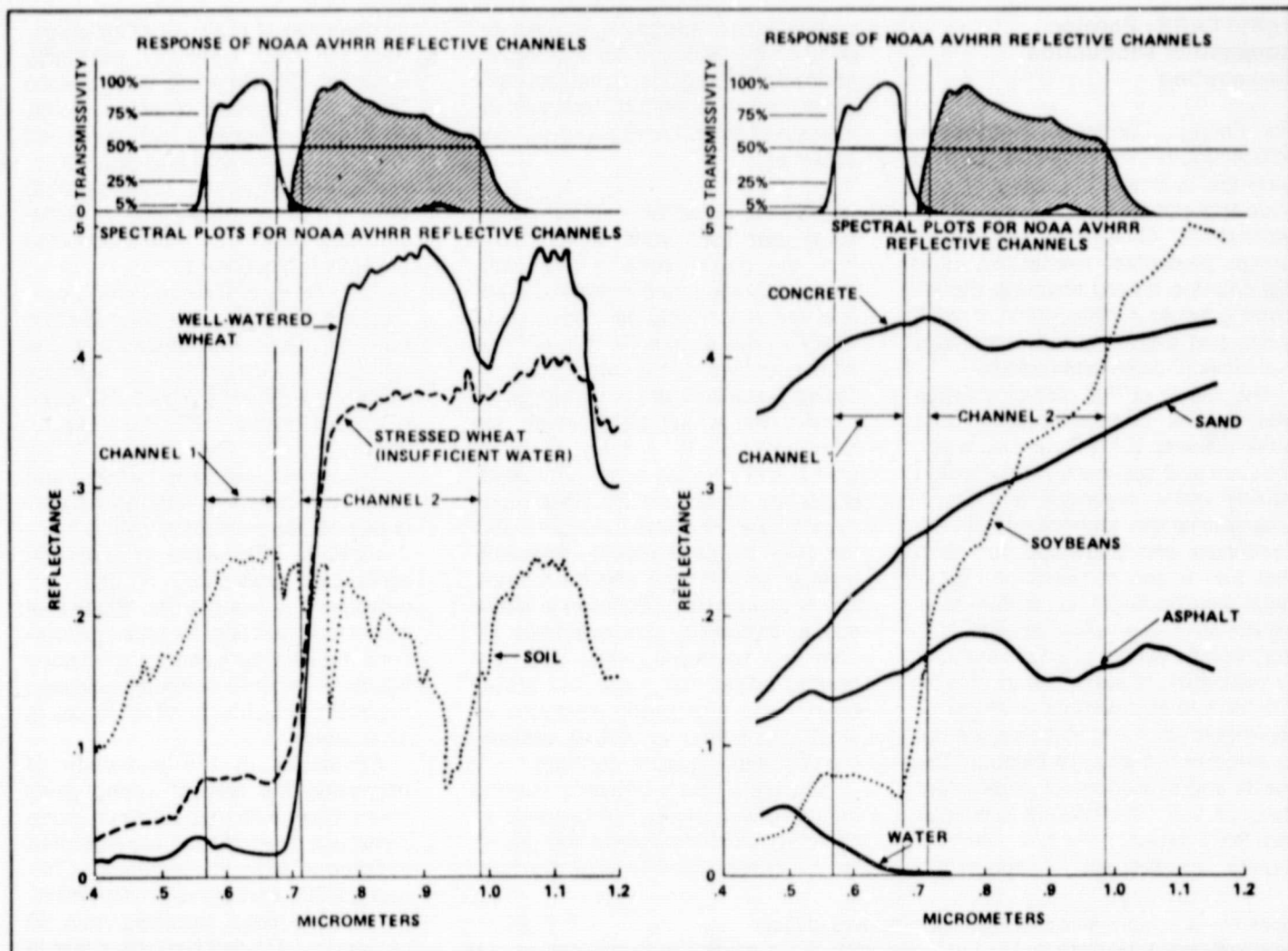


Figure 2.— Comparison of NOAA 6 and 7 advanced very high resolution radiometer (AVHRR) response (top) to reflectance of selected surfaces (bottom). The response of AVHRR is well suited to separate vegetation from other surfaces and healthy from unhealthy vegetation.

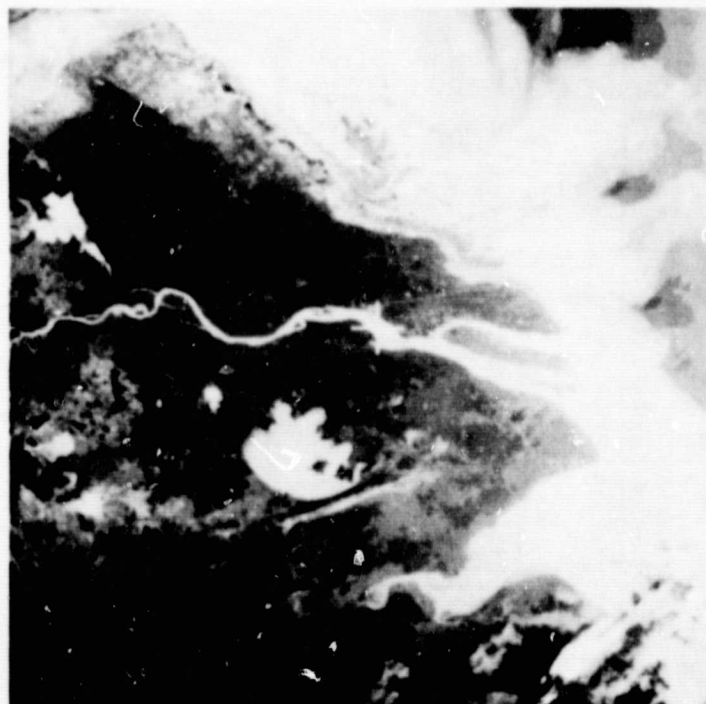


Figure 3.— Mouth of the Yangtze is viewed by NOAA-6, July 14, 1981 (1 km resolution). Blue is assigned to channel 1 and red to channel 2 (the deeper the red, the more vigorous the vegetation). This scene was recorded on a disk ready for analyst use on July 16, 1981.

AgRISTARS: Foreign Commodity Production Forecasting

The Foreign Commodity Production Forecasting (FCPF) project is building upon the technical capability of previous research to further advance the applications of remote sensing to foreign production forecasting. It is test-oriented toward resolving the remaining issues in observation of small grains and extending the technology to additional crops and regions.

The scope of this project involves small grains over selected regions within Canada, U.S.S.R., and Australia, and corn and soybeans over selected regions within Argentina and Brazil. Area estimation technology will be developed and evaluated for each crop and region combination. Technique development and problem solving will be performed in "similar" U.S. crop regions (where good ground truth for evaluation is available) in parallel with the foreign crop regions where independent data and statistics are not as extensive, timely, or reliable. The quality and availability of government statistics vary from country to country and from region to region within a country. Assessment of achievable

performance in foreign regions will depend on the performance assessment in similar U.S. regions, as well as comparison to independent foreign estimates and limited foreign ground data available.

AgRISTARS activities in FCPF during fiscal year 1981 were scaled down from the major research and technology activities mentioned in the annual report for 1980 as follows: crop regions now number 9, not 12; five other countries, rather than six, are involved because India is no longer included; the wheat-barley study has been reduced to a study of small grains; and rice has been eliminated. Budgetary considerations are the primary cause for these changes. JSC has given the Environmental Research Institute of Michigan and the University of California at Berkeley a major role in improving area estimates for corn and soybeans, while JSC has concentrated on more accurate, timely, and less costly estimates of small grains area, as well as evaluating corn and soybeans methods.

Satellite-aided methods for making improved crop production forecasts in selected countries without the use of ground observations remains the over-

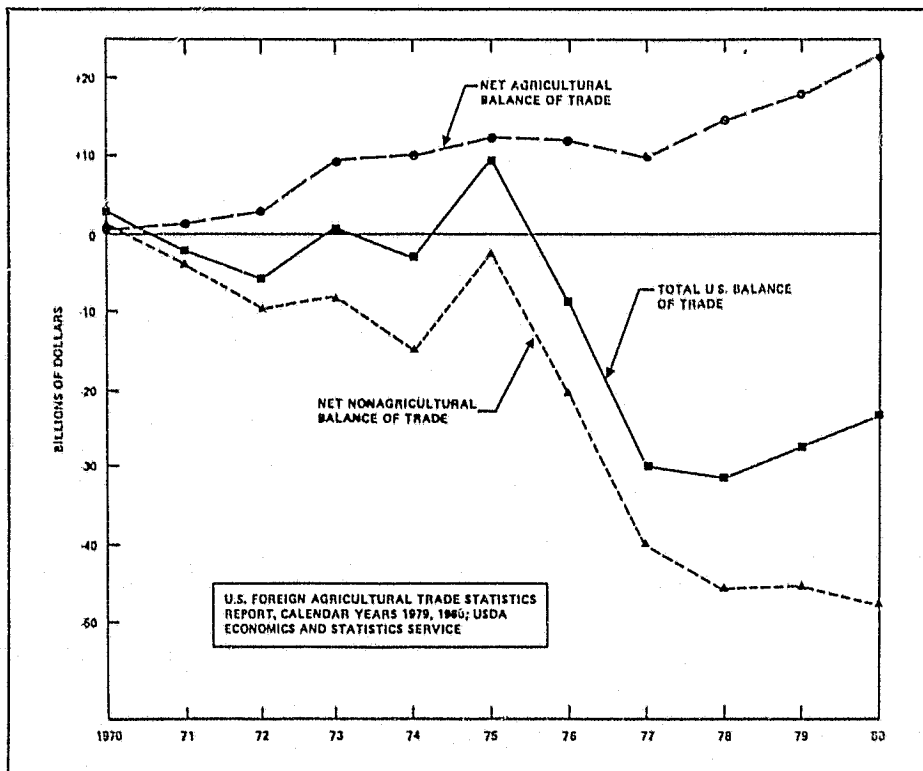
all objective of FCPF. Specific objectives for 1981 were (1) evaluating methods for obtaining late season figures on acreage of small grains, corn, and soybeans; (2) continued reduction of the time and costs of information extraction from satellite data; and (3) initial research on extension to Argentina of U.S.-based area estimation procedures.

The effects of improved timely estimates of global agricultural production have so many ramifications that it is difficult to determine an accurate monetary evaluation figure. However, billions of dollars in U.S. trade are involved (fig. 1). Decisions made by businessmen, individual farmers, and those who determine national policies or procedures are certainly strongly influenced by information on worldwide agriculture production. A little improvement is worth a lot. Studies of global food and fiber for future generations indicate the need for production figures in order to promote increased regional production to offset losses in other areas.

Advances in the accuracy of estimating the area of spring small grains through applied research, using aerospace to advantage, are illustrated in figure 2. Note that differences between FCPF and the reference standard (USDA) have narrowed from 30 percent in 1975 to 9 percent or less in 1981, with deviations about the average as shown, and support of within 10 percent accuracy, 90 percent of the time.

Also, improvements have been made in statistical estimation for the proportion of a sampled area that is planted to summer crops (peak growth in summer) and a further breakout into corn, soybeans, and other crops. Summer crop areas were in agreement with ground observations on 1978 data, and 2 percent high on 1979 data. This level of accuracy, comparable to the spring small grains area estimation, was accomplished in 2.5 years of research through the use of experience gained in dealing with small grains over the past 7 years. Analyses tend to overstate the area of corn, and understate that in soybeans, compared to ground observations. The 1981 analysis of crop year 1978 figure for corn was 15 percent high, and decreased to 6 percent high on 1979 data. Soybeans were 19 percent low

Figure 1 -- U.S. agriculture's contribution to balance of trade.



for 1978, and 3 percent low on 1979 data. Additional research indicates improvements in these relative differences.

Recent research was directed at understanding and automating analysis of aerospace data. In an effort to reduce costs, the results of this research, with additional refinements, was brought into application during fiscal year 1981. Evaluation of a procedure, which is almost totally automatic, indicates analysis can be reduced to 0.5 hour per segment and still sustain or even improve accuracy. In 1975 it took 12 hours to process a segment, as shown in figure 2. Currently the number of segments that can be processed by one analyst in 1 day is 16, for a significant increase without loss of accuracy.

A corn and soybean experiment in Argentina is now planned for fiscal year 1983. Ground truth has been collected from 16 locations in Argentina during fiscal year 1981 and will be digitized into a computer for development and verification tests (see fig. 3). A similar area in the United States has been designated for development of procedures that, with modifications,

may be applicable to that country (see fig. 4).

The basic significance of these factors — increased objectivity, accuracy, and efficiency, and thus improved productivity — is that USDA, or any user, may soon be able to process sample

segments from a country or region with just a few analysts and obtain an accurate crop area estimate in about 1 week. When accurate, timely crop yield models are available, the area of estimates can be combined with these to produce accurate, timely crop production estimates.

Figure 3.— Argentina indicator region.

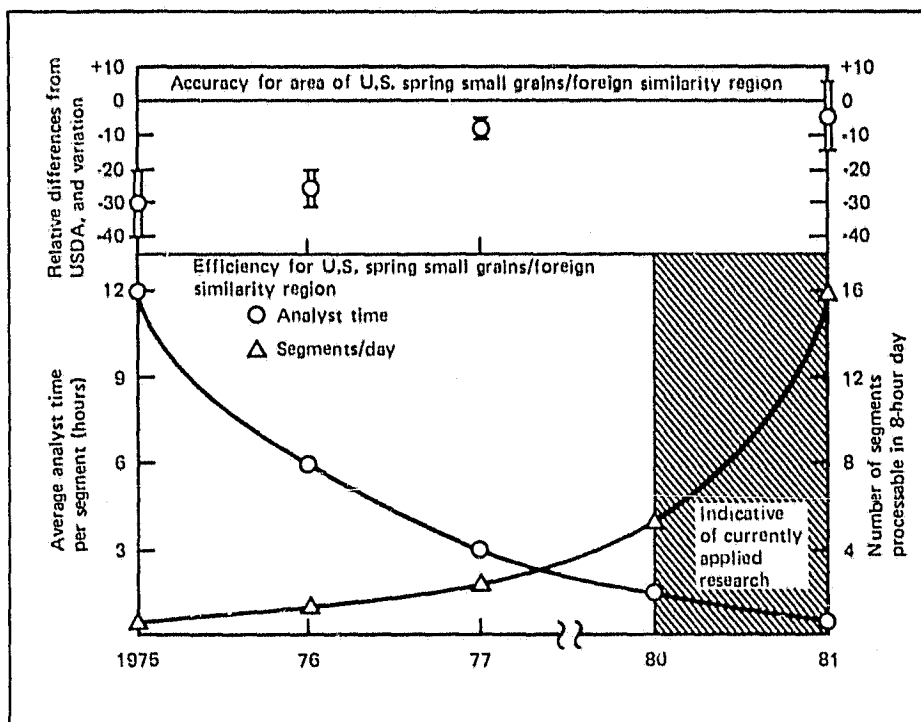
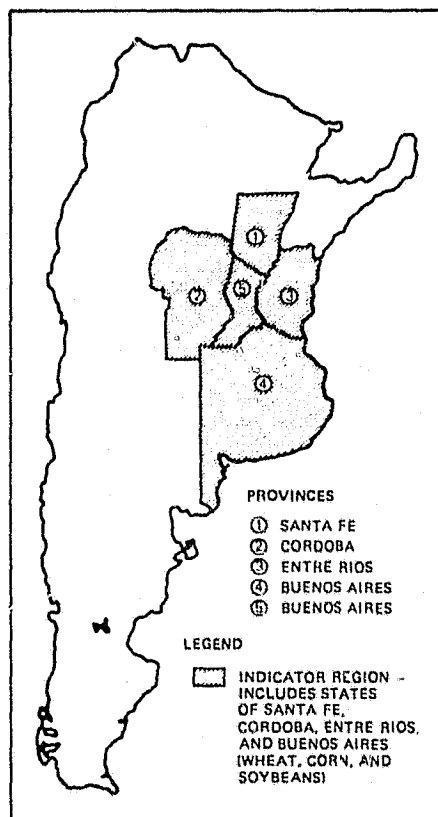
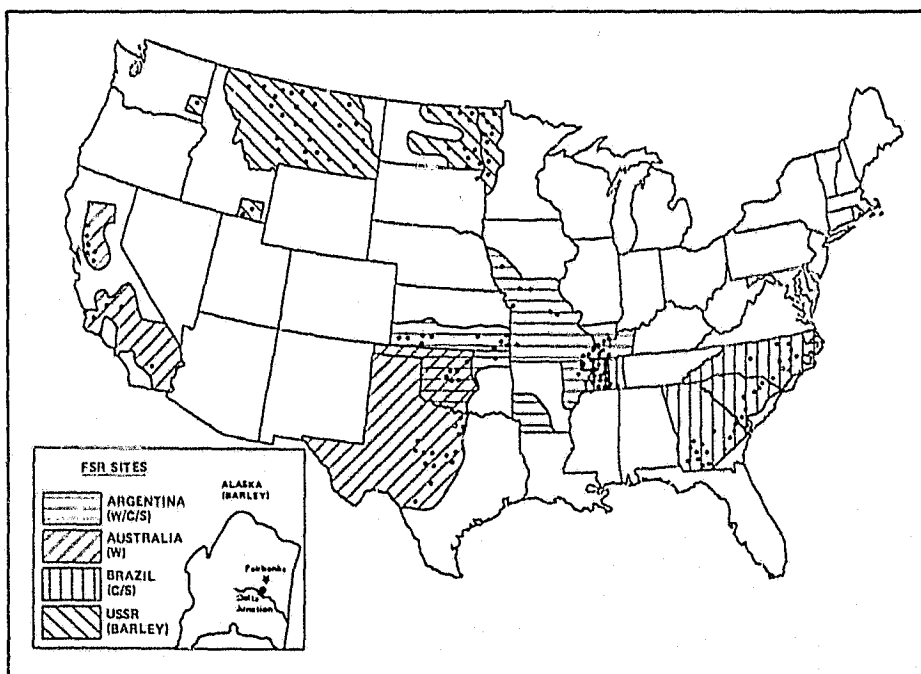


Figure 2.— FCPF achievement of increased accuracy and efficiency.

Figure 4.— United States foreign similarity regions, 1981.



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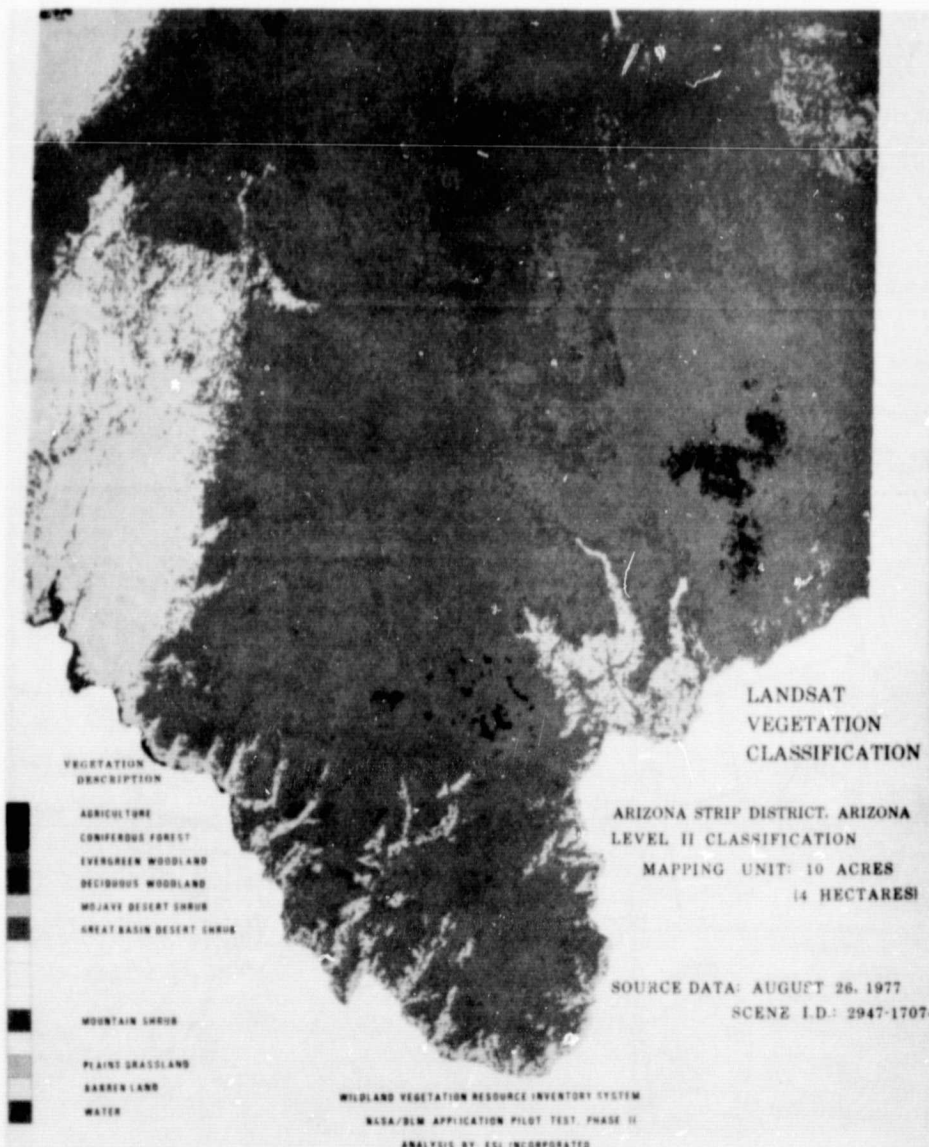
Wildland Vegetation Resource Inventory

The Application Pilot Test (APT) was a collateral venture between NASA and the Bureau of Land Management (BLM) of the Department of the Interior to test and implement an interactive Wildland Vegetation Resource Inventory System based on remotely sensed data and oriented to BLM state and district office management requirements. Planned in three phases with test sites in Alaska, Arizona, and Idaho, the project was initiated in May 1977 and completed in September 1981 with delivery of the final documentation by the NASA contractor.

Training and experience gained by BLM during the first two phases, along with their purchase of a minicomputer system and establishment of the Branch of Remote Sensing at the Denver Service Center (DSC), provided BLM the opportunity to independently exercise their capability over the Idaho Test Site. Transfer of the system to BLM and project documentation were completed during this third and final phase of the APT.

The interactive system and capabilities developed by BLM as a direct result of the APT has proven to be very beneficial as an added capability for inventorying and monitoring the lands under their management. BLM/DSC is applying Landsat remote sensing technology to projects in four western states — two in Arizona, two in Idaho, two in New Mexico, and two in Wyoming. These projects are in support of soils, vegetation, and fire management studies. Other BLM state offices have requested assistance and more than a dozen proposals are being evaluated for implementation in fiscal year 1982 and beyond. The final project review, originally scheduled for early 1981, has been rescheduled for December 1981. The ready acceptance of this new technology by the BLM and increasing requests from their state and district offices for assistance is evidence of the success in using Application Pilot Tests for dissemination of new technology.

Landsat vegetation classification of the Arizona Test Site.



Texas Natural Resources Inventory and Monitoring System

The purpose of this project is to develop, test, and evaluate approaches and procedures for integrating Landsat and other remote-sensing data with more conventional data sources (e.g., census, maps, and field surveys) to augment and make more effective the existing information data base supporting Texas natural resources management agencies. The major goal is to integrate the use of Landsat and other remote-sensing data into the day-to-day decisionmaking processes of the Texas resources management agencies. To accomplish this goal, the utility and cost-effectiveness of the information derived from remotely sensed data must be evaluated in an operational environment using ongoing management requirements of selected state agencies as evaluation criteria.

This project is a joint effort of JSC and consortium of 13 Texas agencies known as the Texas Natural Resources Information System. The project started in June 1978 and is expected to span 4 years. The project will develop, test, and evaluate a Texas Natural Resources Inventory and Monitoring System based in part on information derived from remote sensing. The system will consist of three components: a remote-sensing information subsystem, a geographic information subsystem, and a natural resources analysis subsystem. Figure 1 illustrates a type of output product associated with geological exploration.

The major responsibility of NASA is to assist Texas in upgrading its existing experimental remote-sensing data analysis capability and to interface this capability with other sources of natural resources information available to the state. The software capability is being developed in two parts. The first part was completed by NASA in early fiscal year 1980. The major responsibility of Texas includes developing the remaining remote-sensing software; expansion of the existing geographic information subsystem; development of the natural-resources analysis subsystem; and preparation, testing, and evaluation of output products.

To carry out the responsibilities of both parties, a Memorandum of Understanding was instituted. Responsibility for management of the project is shared by a Texas Project Manager and a JSC Deputy Project Manager.

The technology developed for this project will be documented for transfer to the public domain through NASA's Regional Technology Transfer Centers and the Computer Software Management and Information Center (COSMIC). Texas will also furnish a final report on the utility of the system and a cost and accuracy analysis study.

Accomplishments during the past year are as follows:

1. Acquisition of aircraft data over the 5 major test sites was completed by the NASA remote sensing aircraft project. This was a major program achievement and permitted startup of data analysis activities in the five major applications test and evaluations projects.

2. The remote sensing data analysis system was completed with the installation of the MATRIX color graphics camera and the refinement of software procedures. It is now possible for the operators to conduct interactive analysis and produce output products in a real-time mode. The system is

capable of displaying raw or classified Landsat digital data and performing data enhancements including contrast stretching, band ratioing, and generating false color composites.

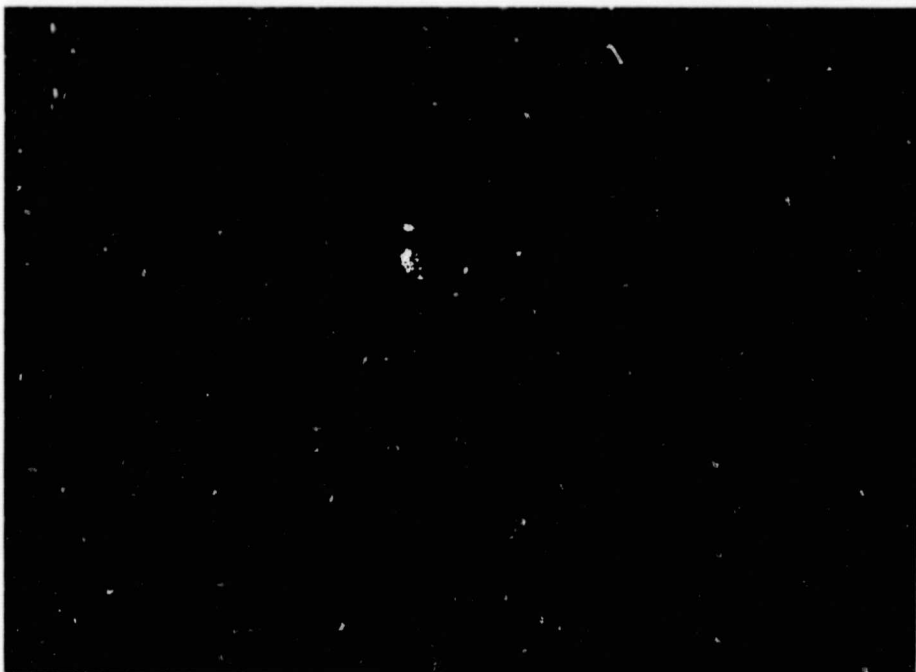
3. Data pertaining to the test sites were implemented on the Geographic Information Subsystem (GIS). Use of this system in conjunction with the interactive analysis subsystem provides a means for integrating and analyzing remote sensing data and various other information in support of specific applications.

4. The research data facility, in Austin, which serves as a data library and screening facility, became fully supportive to the project and various state and local governmental organizations. The data library was enlarged through continued acquisitions of remote sensor and ancillary data.

5. Training courses in remote sensing data interpretation and interactive analysis on the state systems were given to employees of the participating agencies.

6. While the project is still a year away from completion, suitable progress has been demonstrated in a number of state applications and state support is expected to continue at the present level of nine full-time and several part-time employees.

Figure 1.— A ratio image of Landsat band 5 over band 4 clearly shows a circular feature known as Red Hill, located southwest of the Chinati Mountains in Presidio County, Texas.



Extended Scene Radar Calibration

The extended scene radar calibration is an effort to verify the precision and accuracy of scatterometers and imaging radar systems used for remote sensing. The precision and accuracy of the airborne sensors must be verified before quantitative radar backscatter data can be gathered. Quantitative backscatter data are required for most agricultural-related applications.

The experiment approach is to carefully measure the radar reflectivity (on backscatter) of a large homogeneous test area (extended scene) with a highly calibrated ground scatterometer system. This test area is then overflown by the aircraft sensors, and the two data sets analyzed with respect to precision and accuracy. This provides a measure of calibration to the aircraft sensors for extended scenes. Data sets are gathered at 1.6, 4.75, and 13.3 gigahertz.

This effort was initiated in 1977, with data sets being gathered each year thereafter. Various types of terrain have been used as test areas over the years. All test sites are located in an arid climate to minimize the effects of surface and subsurface moisture.

Initial testing was performed at Northrup Strip on the White Sands Missile Range, New Mexico. However, this site proved unusable because of subsurface moisture. Testing during the last few years has been performed at the Jornada Experimental Range near Las Cruces, New Mexico. Test sites of various degrees of surface roughness were created for each data-gathering sequence by plowing up the ground. During fiscal year 1981, an additional data set was gathered using a test site with two degrees of random roughness and another with a simulated row effect due to plowing.

Figure 1 shows the JSC C-130 aircraft overflying the test site while the ground scatterometer system was in operation.

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Figure 1.— JSC C-130 Aircraft overflying the test site.



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SIR-A Antenna Integration into Orbiter

The Shuttle Imaging Radar (SIR-A) — developed to evaluate the potential of spaceborne imaging radar as a tool for geologic exploration and, in general, for mineral exploration, petroleum exploration, and structural mapping — is part of the Office of Space and Terrestrial Applications (OSTA)-1 payload to be flown on the Space Transportation System (STS) second mission. The SIR-A antenna was developed by JSC to be used with the SIR-A electronics developed by the Jet Propulsion Laboratory.

The SIR-A antenna, manufactured by Ball Aerospace Systems Division, consists of seven microstrip array panels mounted on a triangular support structure. The antenna is attached to the OSTA-1 pallet by an aluminum truss structure. The nondeployable 9.44- by 2.1-meter antenna is mounted in the payload bay in a fixed position at 47°. Thermal protection is provided by the multilayer aluminized mylar covering the support structure and by the Beta cloth covering the total system.

The 400-pound antenna system was reinstalled on the OSTA-1 pallet in the cargo integration test equipment (CITE) stand in the Operations and Checkout building at Kennedy Space Center in January 1981. Final alignment was successfully conducted in the CITE in March 1981. Electrical checks (continuity, coupling, VSWR) were successfully conducted in June 1981. The OSTA-1 pallet with the SIR-A antenna was installed into the Orbiter (fig. 1) in July 1981, the alignment was verified, and electrical tests were successfully repeated. The SIR-A antenna system is ready for the STS-2 mission.

Figure 1.— SIR-A Antenna mounted in Shuttle spacecraft.

